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Japan
Intelligent Manufacturing System (IMS) Program

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NOTE TO READERS: Effective 1 October, the processing indicators appearing in brackets at the start of each item will be changed. All new indicators will begin with "FBIS" to make the material more easily identifiable. Some will also indicate whether the item has been translated from the vernacular or transcribed from English.

IROFA-Led Roundtable Discussion on IMS

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[Participants: Toshio Andachi, head of Industrial Machinery Division, Machinery and Information Industries Bureau, Ministry of International Trade and Industry (MITI); Eiichi Ohno, executive director and director of development, Mitsubishi Electric Co.; Yuji Furukawa, head of engineering, Tokyo Metropolitan University; Hideyuki Hayashi (Chair), senior executive director, International Robotics and Factory Automation Center (IROFA)]

[Text]

Hayashi (Chair): Thank you for taking time from your busy schedules to participate in this discussion.

Japan proposed the IMS (Intelligent Manufacturing System) program at the end of 1989 as the IMS international collaborative development program to solve common problems that currently face manufacturing industries worldwide and to develop a sound structure for the future. I believe the most important idea in this program extends beyond mere competition to an original experiment on what kind of cooperation will occur in research and development.

Experts from all over the world also understand this idea. However, this was the first attempt to involve a number of countries in an extremely large program. In particular, the problem of intellectual property rights (IPR) and government-related financial support were also included within the program's framework. The proposal of "slightly more examination of the framework for the concrete IMS project before implementation" was particularly strong from the United States and Europe. Thus, an international feasibility study began in February 1992.

Gathered under the framework for implementing this IMS project in the feasibility study is one more new trial in the form of test cases on how well a large-scale international joint research function will be carried out through a few specific temporary projects. That is, various problems will probably arise during the test cases. The purpose is to provide feedback for these problems in the examination of the framework and to devise an improved framework.

The test cases began with a two-year schedule and have just passed the one and a half year mark. The first year was divided into studies of the test cases. Today, six test cases are proceeding in the form of international consortia. We are currently approaching the stage of stimulating discussions on the essential objective of examining the overall framework of the IMS project.

Although we are still in the feasibility study phase, in this panel discussion, I would like to hear your thoughts on the central point of how the IMS project will develop in the future.

I think broaching this topic from the beginning is somewhat difficult because over four years have passed since Japan's proposal. As panel members who have taken part in the planning of the international committees established during the feasibility study, what are your thoughts and impressions of the progress of the IMS project?

Let's first hear from Professor Furukawa who has participated since the IMS project's planning stage.

Past Development of the IMS Project

Furukawa: As Mr. Hayashi noted, I'm sure all of us are grateful to have finally reached the end of the feasibility study.

I will begin with my opinion on the international management of the three committees of the International Steering Committee (ISC), the International Technical Committee (ITC), and the International Intellectual Property Rights Committee (IIPRC). There are a total of 10 committee members representing all of the countries. My impression as a committee member is that the members in each committee are very enthusiastic. I strongly believe that all want this international collaborative research to be a success. Although there have been arrangements between two countries on different international joint research or joint research between private corporations, this is the first attempt to perform large-scale collaborative research of three or more countries. The fact is the committee members from all over the world are quite passionate about this.

However, despite the enthusiasm of each committee member, I am concerned about various problems such as political, economic, and social problems which exist in the country or region of origin of each member. These will burden the committee member and some gap may exist between the country's industrial policy and individual inclinations. If only the opinions of individuals were combined, it would be a simple matter to solve. However, cooperation between the people of different countries must develop and this is very difficult. So when viewed from the perspective of people who are not participating in this project, they may have the impression that the program isn't advancing at the rate proposed by Japan. I believe that promoting international cooperation in this situation is quite difficult.

Chair: Thank you. Mr. Ohno, what are your thoughts?

Ohno: As Professor Furukawa stated, international cooperation is a critical point. Although IMS stands for Intelligent Manufacturing System, the "I" has also stood for "International" from the beginning. Perhaps it should be IIMS where international cooperation forms an important foundation of IMS.

There is a variety of academic conferences related to manufacturing technology, for example, conferences about robots. In my industry, I too have been involved with various academic conference activities due to my

many years of working in research and development. However, IMS is not simply at the level of an academic conference, but encompasses the larger meaning of an organization that includes countries, regions, or the whole world.

New technologies were introduced into Japan's manufacturing industry during the 1970s and 1980s. Developments came from flexible manufacturing systems (FMS) to factory automation (FA) and computer-integrated manufacturing (CIM) and competence has been cultivated in these areas. In the 1990s, and as we move towards the 21st century, it is important to consider what industry should do. While the current economic climate is poor, this is not simply a short-term problem. We approach a major crossroads in the 21st century and it will be an era of structural change. How should manufacturing industries change in this era can be debated on a global scale. I believe this will be quite beneficial. In this context, much is expected from IMS.

Chair: Mr. Andachi, what do you think?

Andachi: Although I participated as a member in the second International Steering Committee held last July, I heard that the first ISC meeting held in Toronto was a remarkable meeting where a discussion on making a framework took place in circumstances where a satisfactory consensus of all regions could not be reached. I have inherited the situation of somehow compiling the results following the second and third meetings. Even when the actions of the actual conferences are looked at, this kind of feeling is increasing. As Professor Furukawa stated, I feel these changes are very dramatic.

As we move towards full-scale research, the government of each country must provide stronger support. A major first step was the "Kyoto statement" at the Kyoto meeting. At the end of the ISC meeting in Venice, Mr. Inaba, a committee member, suggested announcing the intentions to the world and issue a statement based on the consensus arrived at in the previous discussions for the Kyoto meeting that must be attended. This was accepted and the position shared among the countries will be clearly presented to the world at the fourth meeting in Kyoto. The Kyoto statement is a powerful starting point for full-scale research.

However, since the regions are different, so are their opinions. For example, looking at the European Community (EC), there is ESPRIT, where critical experience was accumulated through trial and error of multiple collaborative research projects within the region. The EC experience is very useful in demonstrating points that must be heeded concerning this kind of multifaceted research. But there are times when Japanese are apt to be impatient with this necessary circuitous discussion. This, however, is useful in avoiding failure. Additionally, I believe the discussions would progress rapidly in three regions, Japan, the United States, and the EC. With the addition of Canada and Australia, when a consensus is formed, I feel they will fill important roles. Frankly, I wonder what will happen as more regions are added, but I feel that six regions would form an excellent structure.

Chair: Thank you.

I also participated in the IMS project from a relatively early stage. Since the FA vision discussion group in Japan in 1988, this examination of IMS has been underway for a long time and, in fact, this was a basis of an older study. I've heard that the United States and some European countries criticized Japan's proposal and there were disputes from the beginning.

Upon hearing your opinions today, I strongly feel the current situation of consensus can be arrived at through this kind of international committee attended by representatives from all countries who exchange a variety of opinions, and these discussions will advance constructively.

Although there are many discussions I would like to have, one is about the test cases of the feasibility study which are underway and will begin their one year schedules in February. The test cases have proceeded well and will play important roles in building the IMS project in the future.

Mitsubishi Electric has undertaken one of the six test cases and is the leader of the international consortium. Would you briefly introduce its state of progress?

The International Gnosis Project

Ohno: This project is called Gnosis, the initial "G" is silent. This word comes from the Greek language and means knowledge.

Professor Yoshikawa, who proposed IMS and is now president of the University of Tokyo, stated from the beginning that this project is the "systematization of knowledge related to manufacturing." Based on this idea, this project was proposed to be assembled domestically, then to become an international project.

As discussed earlier, when assembling an international project, the first problem is the balance between each region and the participation of as many regions as possible is desired. Therefore, IMS is an international problem and at the same time attempts to successfully form collaborative relationships between experts at universities and public research institutions, and groups that perform research in the private sector. Initially, in order to create a global international project, the structure of the consortium was to have all six regional members participate in the planning. In the case of Gnosis, Australia did not participate, although the other five regions took part. There was an imbalance in that a number of organizations from Japan, the EC, and the European Free Trade Association (EFTA) participated, while only a few Canadian and American organizations participated. I think this first test case barely earns a passing grade. In this case, a total of 31 academic, research, and corporate organizations participated.

Japan had 8 organizations participating; the EC had the most at 11; EFTA, 8; Canada, 3; and the U.S., 1.

A while ago Mr. Hayashi stated that it had started at the beginning of this year, in fact, a review was held at the 3rd International Technical Committee (ITC) in Dallas, Texas, last November. Previously, the structure of the consortium had been settled and because no proposals were submitted on its content, various activities were started back then. This phase was very troublesome and our group leader toured the world and assembled the group. This project was approved at the Dallas meeting and Professor Furukawa explained it to us today.

Later, a formal decision was presented at the beginning of this year and initiated. Therefore, members from all 31 enterprises that joined this consortium were not present at the beginning of February, but a majority of people attended the Inter-Regional Meeting (IRM) held in Stuttgart. Since the test cases will only last about one year and everyone will not work from the beginning to the end, the so-called work package is divided among about five groups.

There was real concern in the first phase about whether it would go well, however, everyone enthusiastically cooperated in this approach. Following the February meeting, the IRM that gathers together the whole group will be held in Helsinki in August, then in Kyoto in November. During this phase, monthly meetings in the form of working groups are held somewhere for each task force. More than 80 people are participating.

The problem in the initial phase was balancing the regions with industry and academia, therefore, prominent members who are hard at work were gathered together. The cooperation of each organization must be obtained in this area. As mentioned earlier, IPR [intellectual property rights] was a problem at that time. This project is a long-term issue and we are working to prevent problems in this area from becoming serious. During this phase, there were many discussions on how to manage a long-term project and specific short-term results. There were discussions on Japan's proposing this project with a long-term view and Europe's desire to also carry out comparatively short-term projects. I think we can execute a program that skillfully combines these two views.

Equal partnerships and equal participation in planning are considered to be one basic principle of IMS. In this context, Mr. Hayashi described our role as the "leader," however, the proper title is not leader but "point of contact." This was discussed in the third ITC. Since "leader" or "coordinator" imply "standing in authority," they are not used. We decided to call the executive manager of this project the "point of contact." Looking at one point of this discussion, the question arises of how will everyone in the world work under a principle of equality. Therefore, we have examined this in depth.

Since this project is international, there is concern about its expense. European and American businesses in particular have expressed doubt on this point. As stated earlier, operations are international, so over 25 percent of total research costs are business trip and communications costs. Since volunteers provide the manpower, providing an official number is difficult, but this is a rough estimate. The expense of this international cooperation is costly, but we recognize that this will help us obtain a collaborative system and superior results. Then, various discussions will ensue based on this, and I believe good things will result.

Chair: Thank you.

Of the six projects, which project has the most partners or participants?

Ohno: Let me see, three of the six are about the same size. We are planning for 32 participants and it is now 31. I've heard the Holonic Manufacturing System has 32 and if this is the case, it is the largest. Because the figure of 31 has been stated in connection to Globeman 21, three projects have over 30 partners.

Chair: Because so many people are participating in the Gnosis project, its administration is difficult. The experience so far has been continuing the research while satisfying collaborative efforts among all of the participants. I would like to hear about each of the other five test cases. They were described at the beginning in the feasibility study and are very significant. Of course, in addition to how research and development can proceed efficiently in this kind of system, a number of problems have appeared. The IMS project to be constructed in the future will truly be a fine program. The International Technical Committee has requested that all experiences and problems be sent to them. I believe this phase completes the initial monitoring, would you please summarize your evaluation or opinion of the current situation?

Professor Furukawa, what is your opinion?

The International Technical Committee's Monitoring

Furukawa: One caveat about the objective of a test case is the mistaken belief that having any result is the objective.

The objective of these test cases, as Mr. Ohno stated earlier, is not to officially or unofficially produce a specific research result in only one year, but to have three or four broad objectives.

Objective No. 1 is to verify whether international cooperation among at least three countries is possible in the manufacturing field. I believe this is the most important objective.

Objective No. 2 is to establish a distribution principle on how intellectual property like patents is to be shared in the collaborative research system.

Objective No. 3, which I feel addresses a critical problem, is when research continues in the future, specifically, how will research topics be established and how will they be managed.

Objective No. 4 is closely related to this problem; perhaps it should be objective 3a. This is the tricky problem of how to administer research funds or personal resources. In the current phase, these three or four important issues will be identified in the test cases.

In order to identify these issues, the decision was made for the technical committee to monitor them, and a monitoring methodology was defined last November. This is called the "monitoring grid" and the monitored items are set up in a matrix form. Monitoring is centered around the four objectives I just mentioned. Representatives of the consortia for the six test cases that began in this year's February phase reported on how the consortia were formed and what problems were encountered in the formation process. During the Vancouver meeting in July, the current status and state of progress were reported by the same six teams and interim evaluations took place. Finally, the plan is to write the final report at the 6th International Technical Committee held at the end of November to sometime in December.

As for content, each of the six projects is proceeding smoothly within the research collaboration system mentioned earlier for handling intellectual property rights and establishing research problems. With an eye on major results in the future, I firmly believe that earnest cooperation and international understanding are being advanced.

The six test cases underway have distinctive features. Although there are test cases in which Japan is not participating, Gnosis, described by Mr. Ohno and Globeman 21 on how to conduct global manufacturing, has British Aerospace Defense Ltd. as the point of contact. Many participants have come from Japan, but I think this international collaborative and apportionment system can be achieved.

In addition, Northern Telecom in Canada is the point of contact for a project that deals with research issues related to concurrent engineering. Here, the communication designer is described by Mr. Ohno as very skillful, as would be expected since it is Northern Telecom. More than directly meeting the person, unfettered use of international communication like E-mail or video conferences is planned. This is very unique.

Then there is the Rapid Product Development project centered at United Technologies Co. in the United States. This advances research content that is intertwined with rapid prototyping, from the computer-aided design (CAD) to the prototype, then introduces the product to the market. I think this is quite substantive.

The Holonic Manufacturing project is being promoted which is centered at Allen-Bradley in the United States. The core problem is to create the elements of manufacturing systems. Evaluation is possible where hardware that is the elemental technology is apparent and the target is easy to understand.

Finally, one project I am very interested in as an individual is the Clean Manufacturing Project. This project is promoted based at ICI Engineering in Great Britain. I felt that, from the beginning, Japan has focused on processing and assembly industries for the production industry and IMS was started at Japan's impetus. When the test cases began, the chemical industry field entered as a link to clean manufacturing. It seems the field in the manufacturing industry will expand further; this is a distinguishing characteristic of this project.

Currently, the six test cases are underway and progressing smoothly, and energy is overflowing. Why international cooperation is necessary and its objective will gradually become clear. We have been given the incentive to collaborate internationally, but it is not clear when collaboration is needed, what the format should be, and in which fields collaboration is needed. In the phase where the six test cases are each advanced, these issues will become clearer in each technical field. I definitely expect this to connect to the future.

Chair: The last comment of the professor was very important.

Furukawa: Yes. I want to add one more thing. Initially, the six technology fields were described at the International Technical Committee. While the International Steering Committee suggested that three or four themes would be suitable as test cases, in the end, six test cases were decided on. The six technology fields explained by the International Technical Committee and the six test cases underway do not necessarily coincide. One missing element in the manufacturing technology requested by the technology committee is the human problem, that of human resources or people themselves is not addressed in the test cases.

It's too bad the test case phase does not address future fields like new materials and new processing techniques. I hope these important fields will be included in the IMS project in the future.

Ohno: As Professor Furukawa stated, I also believe a major objective of this international cooperation, especially the feasibility study, is to see whether international cooperation will be successful. Therefore, in addition to holding meetings, new methods are steadily being employed like the presentation from Northern Telecom in Canada teleconferenced during the fourth ITC meeting in Sydney. In addition to meetings of our group, new communications methods like E-mail are steadily being used. Europe and the United States are rapidly expanding E-mail, but it is limited to a portion of researchers in Japan where it seems to be spreading more at universities.

Furukawa: Universities have many fax machines.

Ohno: Faxes are used a lot in Japan, but E-mail still has a way to go. While it is used in particular research groups at laboratories like ours, it is still not common. However,

when I exchange business cards at meetings with colleagues from abroad, since E-mail is widely used, they ask "Do you have E-mail? What is your E-mail address?" Japan is a little behind in this area. Another aspect is a cultural difference where using faxes to send handwritten characters and drawings is widespread in Japan. In any event, it is important to skillfully use these techniques.

A communication system for efficient mutual exchanges and ways to record and manage the data are also essential.

Chair: That's true. Although this is unrelated to the IMS project, one of our projects at IROFA is the MAP project to solve the networking problem in a factory through international cooperation. A World Alliance meeting will be held on this. Until now telephone conferences have also been used, but not very frequently. Starting this fall, however, a time frame will be appropriately set so that everyone from all over the world can participate once a month, making the conferences more frequent.

When a project becomes international, you can't wait for mutual communication or meetings. Since there are large increases in costs and structural costs in nonessential overhead, this area will probably be strengthened in the full-scale IMS project.

Andachi: No matter how the full-scale program proceeds in the future, teleconferencing has become another topic of discussion. After selecting six test cases, the task force will teleconference their meetings. Although the Canadian representative initially seemed to be lost at roll call, this was an effective method given the pre-conceived notions. Looking at costs, they can be reduced by about one-tenth compared to discussions in face-to-face meetings. While the teleconferences have not gone very well so far, I firmly believe an important issue is to skillfully combine them into multifaceted collaborative activities.

Furukawa: We are currently studying setting up technology themes in a working group of the technology committee and teleconferences are common with my colleagues. However, there are two difficult problems. The teleconferences are always held at 12 hours Greenwich time, but this is slightly different depending on the region at the beginning and end of summer and the person called may not be present because of the one hour difference. We missed out a number of times before summer. Either people weren't there or they were there, and in fact, I, the ringleader, was also late at times. Such a simple thing can be quite difficult.

The other problem is the Japanese are unaccustomed to being chairman. For example, at my university, to use the telephone circuit for simultaneous calls to five other countries, a reservation is made and this cannot be performed systematically. With this kind of problem, perhaps Japan is a backward country in terms of unexpected phone calls.

Chair: Thank you for sharing your opinions. So far we have heard your opinions on the progress of the feasibility study in particular. To summarize, the feasibility study, which includes the test cases, has increased the confidence among the participants, and everyone will strive to make the IMS project a reality in the near future. In the future, we at the IMS center will also work hard to create an excellent program.

Finally, I would like to broach the main subject. The feasibility study will tentatively last for two years. Mr. Andachi, please summarize the major issues in the future development of the schedule and IMS framework for the remaining six months.

Future Issues of the IMS Project

Andachi: As Professor Furukawa explained earlier, the final evaluations were made in relation to the feasibility study raised in the final phase and they will be reported. Upon hearing this, it appears that each of the six test cases are proceeding smoothly. But a few problems are acceptable. The overall feasibility is the process of reporting what went well or didn't go well, including the creation of full-scale, serious research. The issue becomes building a framework for serious research based on the feasibility study that focused on the test cases.

In fact, wasn't the Kyoto meeting the starting point for building a framework for serious research? Members of ITC and IIPRC combined to form a task force at the International Steering Committee and will become the forum for future discussions. In addition, this work will proceed while the roles are aptly assigned to the four working groups in ITC and examined by IIPRC subgroups.

The Terms of Reference created in the feasibility study describe what must be included in future discussions. We must investigate whether it is good to truly include this unchanged into the full-scale program. When each specific issue is considered, there exists the issue of thinking about the method for participating in IMS. For example, the six regions of Japan, the United States, the European Community, the European Free Trade Association, and Australia are now participating in this program. Other countries like Russia, Korea, and Singapore have asked "in what manner can we participate." One major problem is what format will be established for participation. Although this problem was suspended in the feasibility study stage, in the end, this must be addressed by serious research.

Even with just six regions, in terms of management and manageability of the project, this is a fairly large number of members. The problem arises of what mechanisms are required for the project to possess manageability and to have an open system.

So far IMS created an IIPRC subcommittee. Based on the results, IMS has given intellectual property rights a very important position because it is important to this

project's success. When new countries participate, the protection of intellectual property rights in each country must be carefully examined.

The related manageability necessitates studies on how to manage IMS project and on the management structure. While various arguments have been put forth, for now, the majority opinion seems to favor promoting a distributed form as the basis. Specifically, it would be wonderful to construct something like a central laboratory where all kinds of research would be performed, but this has problems in terms of efficiency. When a secretariat system that supports research activities was decided, the question was what is the best way to provide smooth and efficient support while maintaining global coordination. This aspect still must be considered.

The six fields selected as test case themes have been described, but is it proper for these themes to become full-scale projects unchanged? Perhaps, it is not. Consequently, we must once again discuss what is the target field of each project that is taken up as a full-scale project.

I feel another important point is how long will the IMS project last. At the time of Japan's proposal, it was stated that "to have an impact, the project should continue for at least 10 years," but this must be an international decision.

Other issues are how will the responsibility for funding be shared, what are the plans for disseminating results, and how to create a smooth transition period from test case to a full-scale project.

Although in the reverse order, the concepts of the objective and the fundamental philosophy of the IMS project must be organized. In fact, discussions on these issues have already taken place. While a portion is addressed in the statement of the Kyoto meeting explained earlier, the fundamental philosophy is being discussed and reviewed. This must be reconfirmed in the future.

This work was launched in Kyoto and discussed in ITC 5 and IIPRC 5 in a subcommittee base. A task force was also started at that time. Discussions by the task force will be held at the 5th International Steering Committee to be held this October in Canberra.

The final evaluation of the test cases has begun under this structure. At the 6th International Steering Committee meeting slated for January of next year, all of the discussions will be compiled and advice will be given on full-scale implementations. I believe the final phase for building the framework for full-scale projects has arrived.

Chair: What will the procedure be when the feasibility study ends?

Andachi: Work on the test cases will end in February. And based on the results of the feasibility study available in January, a final report for full-scale research will be presented. The procedures for the participation of each country will be based on this final report. When this ends, work for beginning the full-scale program in April will go into action. The appeal for applications for themes for full-scale research will go out in the summer. This will probably continue from early fall to winter. The tentative schedule is for final selections and decisions to be at the beginning of the year, which I believe is appropriate, followed by selections of proposals for the first fiscal year, then each consortium will begin research.

Chair: Thank you.

Mr. Andachi has indicated several points that must be studied in the future. I think each one is important. For the IMS project to be understood and promoted, the objectives of the IMS project not only have to be understood by Japan, but must be understood by each country that will participate or wishes to participate.

I believe the objective will become clearer in the future, but please tell us what kind of studies the current International Steering Committee is carrying out?

The Meaning of the IMS Project

Andachi: I will relate the confusion I felt as a secretariat. A portion of the objectives pursued by the IMS project was briefly introduced in the Kyoto statement touched on earlier. Although the reasons given were global environmental problems, efficient use of natural resources, and working life, current actions address shared international problems which directly descend from measures for improving the quality of industrial life, addressing the globalization of manufacturing activities, and the intellectual system connected to inventions. These are summarized in one paragraph.

For example, in relation to "improving the quality of working life," it is often said in Japan that "young people are estranged from manufacturing." While the factory workers themselves hate the dangerous, dirty, and demanding work, with the current sluggish economy, this is no longer the case, but it is a mid- and long-term phenomenon. Recently students in scientific fields have been slowly returning but it's been emphasized that they do not always aim for manufacturing. However, this seems to be a global problem.

Therefore, the opening of the Kyoto statement that asserts "manufacturing requires creative people who are its principal wealth, and the establishment of a sound foundation for economic growth" is a starting point for the fundamental concepts of the regions participating in the creation of the IMS project. The common issues are to again recognize the importance of making things and how to skillfully develop this. When the position of the IMS project is viewed from Japan's perspective, the Japanese government's perspective rather than everyone's objectives, given the tense trade friction, each

country is in a bind in relation to next-generation manufacturing technology and are in conflict. I don't think this friction will be resolved.

Major points of the friction problem are the trade imbalance and the imbalance in income and expenditures. Perhaps, friction will not end even when these imbalances are eliminated. On a micro level, they will not be eliminated if the proper measures are not taken. In the pursuit of more harmonious relationships, there is no mistake that the trend must be to share next-generation manufacturing technologies and to work together beginning at the development phase. Through the participation of each country in the IMS project, an important issue is gaining sympathy and understanding concerning ideas on the variety of manufacturing policies from the United States and other countries. Although this may be a biased view, this is how I feel.

Also, the objectives of the Kyoto statement include global environmental problems and the efficient use of resources as shared problems. The point of view of how to rationalize global environmental problems and energy use in IMS discussions were not in the initial phase. But I feel this point occupies more weight recently. The addition of clean manufacturing is not a unique phenomenon.

Outside of points touched on lightly in the Kyoto statement, naturally, a major issue is how to technically address problems shared worldwide on a basic level to respond to the diversification of needs on the demand side. Isn't it crucial to wrestle with internationally shared problems including this one? For the most part, this will be adapted in the discussions.

Ohno: The full-scale program will probably be realized as prescribed in the Kyoto statement discussed earlier. As one vision, the Kyoto statement is a very clear expression since it is valuable to everyone and specifically relates to how to execute this vision. Various technologies are emerging just to tackle current global environmental problems. Since each country worked separately, only its own situation is considered. However, with environmental problems, if China uses coal, the pollution comes here. As a result, global thinking is truly a necessity. It is important for IMS to clearly state how to organize the objectives for various possible technologies. Since the full-scale program will last 10 years or some very long period, this will not be "simply practice for international cooperation" as in this feasibility study and results will be demanded. Given this context, because people from all over the world are gathered, expenses are paid, and labor is offered, I feel the main questions are do the results meet the objectives of the Kyoto statement and do they benefit people and the world.

Specifically, centering on the current six regions or each participating country and region, as stated earlier, the problem is how will other regions enter. In the end, the ideal is for the whole world to participate in the planning and for everyone involved with planning in the manufacturing world to participate, but when will this step be adopted.

The current situation of the increasing gap for many developing countries, especially in our Asian region, and advancing international cooperation is difficult. This type of problem will be more evident in the 21st century. Environmental problems or problems of resource utilization must be considered.

Chair: Professor Furukawa, what do you think?

Furukawa: Since I work at a university, I've been asked innumerable times "first of all, what is IMS?" At those times, I responded to make them consider the following. When IMS is intelligent in a scholarly or technical sense, it becomes a world with a very narrow meaning and will be limited to research and development fields. In fact, however, as Mr. Andachi stated, IMS is a comprehensive program or project. Please understand the reason for not specifying its content.

I truly admire the leadership at MITI. At the time Japan initially proposed IMS, Europe made the counterproposal of the Future Generation Manufacturing System (FGMS) and the United States made the counterproposal of Advanced Manufacturing, namely, advanced manufacturing systems. As program names go, their names are better, more inclusive. In the end, the IMS name remained and it not only involves research, but you should understand it remains as a project and the project name.

When asked how this has changed over these five years, I think in Japan's view the initial proposal related to isolated automated islands or what should be done about the alienation of young people from manufacturing industries. Then in the Terms of Reference of the feasibility study introduced earlier, participating countries will prevail based on manufacturing industries. Everyone will become winners. Finally, the future summarized in the Kyoto statement has manufacturing industry as the axis in possible future programs. The result is that environmental problems, human problems, societal problems, and natural resource problems will be considered.

Considered in this way, from the initial proposal to today and into the future, the axis has the mainstay idea of increasing the overall wealth of humanity by having the manufacturing industry become less selfish. All of the countries currently participating share this understanding. The remarkable aspect is the agreement to mutually share technology to support manufacturing industries. As Mr. Ohno stated, if this agreement expands to Asia's newly industrializing economies (NIEs) or expands to other regions, it would be quite remarkable.

Incidentally, a proposal of Mr. Harmon, a member of ITC, is to create an event that resembles the International Manufacturing Forum. That is, this is connected

to formally establishing a place for exchanging technical knowledge. Not only Japan, but if people from all over the world understand, I expect it to be connected to the development of solid manufacturing industries.

Andachi: I would like to comment about the expansion of participating countries. Although in theory the whole world will be covered, the IMS project must produce decent results. Although this is a little off the topic, when considering that careful attention must be paid to how to manage the presentation of these results, occasionally in my previous job, I created legislation for large-scale regional promotion for facilities in regional base municipalities. This was limited to the participation of six agencies and ministries, not six regions. In fact, the ideal is for the whole government to be involved, but projects where almost all the agencies and ministries participate did not work. The general idea we held was to approve participation in response to the contribution.

Therefore, the leadership role mentioned earlier is a delicate problem of which ministry will be the leader. This is also the role of a convenient arranger, an anchor, and a contact point. Well, the argument is who will it be.

This is very domestic, but the international politics has an unusually domestic nature. Participation from areas outside the six regions will have its own brand of excellence and we must look at the contributions for producing results in this case. The two problems of least developed countries (LDC) are the problem of how should LDCs be included in collaborative research and the problem of generous technology transfer for making objects. When these become confused, skillful management of collaborative research is not carried out. Certainly, the ideal was very high, but results were not offered and no work was accomplished. As we enter the phase of rapidly pursuing results in full-scale research, the important points become how to differentiate between these two problems and the problem of managing the return of the results.

Furukawa: Without a doubt, there is a gap between the ideal and reality. The reality in the first principle is the project must proceed successfully. The second principle is there must be merit to a participant's participation. Ideally, the output of results should lead to technology transfer to developing countries. Tacit understandings or points that have emerged in the discussion have been the problems ranging from funding responsibility to managing intellectual property rights at the present technological level or international cooperation level of the participating countries. I believe the expression in Mr. Andachi's words is "obtaining a balance." The understanding reached was if the range of the participating countries is constricted by the word "equality," there will be no real progress.

Thus, if a more realistic interpretation is made, there is a need to understand what will be the criteria, for example, at the Organization for Economic Cooperation and Development (OECD) level. Another problem is how to transfer the output. As Mr. Andachi states, this becomes confused and incoherent and nothing happens.

Ohno: But I think the latter type of transfer must occur to some degree.

Furukawa: Yes, that's true.

Andachi: From our perspective as amateurs, technology transfer has sharp reverberations. However, when technology is transferred to some countries, a real problem is the almost total absence of translations in the local language of ordinary technical books found in Japan's bookstores. Translating basic technical books takes time and effort. We must begin by addressing how to carry out this task. Although words are fine, in reality a great deal of slow but sure effort is needed.

Although the technology transfer problem is not completely resolved in the IMS system, in my view as an amateur, it is probably included in various other activities and is moved forward by one or two steps.

Furukawa: Therefore, when the promotion is not very conservative, problems occur. A main problem of IMS is promoting "technical innovation in manufacturing technology." The participating countries are aware that "current technology must be standardized in order to promote technical innovation." The view taken is "if the participants standardize, this would also be useful to developing countries like NIEs and becomes a merit." However, if the standards are overspecified, when looked at from the perspective of the developing countries, "standards are the logic of the strong." However, participating countries have emphasized that this is not so. Furthermore, the issue raised by Mr. Ohno was technical knowledge must be adjusted for standardization. A methodology for adjusting is needed to achieve this. This logic was required in the Gnosis test case. Well, I think it is difficult to gauge how useful the knowledge system advanced under Gnosis will be to developing countries.

Ohno: As you say, the problem of developing countries is serious.

I believe Professor Furukawa said earlier that the theme must include more human factors. These kinds of problems are the problem of the awareness of the people working at actual sites in each country and various environmental problems which differ between the participating regions. In addition, the greater differences between developing countries have not appeared at the surface. This is definitely a serious issue.

Andachi: Although this may be a little premature, six regions are not seven or eight. Korea or Singapore should be included based on the circumstances of each project. Other participants endorse the consortium structure. In addition, with the preconditions of no problems in the country's handling of intellectual property and mutual consent under common rules, a country can enter as a partner in a project.

Chair: In the proposal made four years ago by Japan, the field was limited to processing and assembly in the manufacturing industry. Current actions cover a wide field in the manufacturing world, specifically, the manufacturing world is the world's economic development base. The important objective offered is the connection to the happiness of all of humanity. If this is so, the number of participants will increase and the ideal will be to have as many people as possible participate.

As the IMS project finally goes into operation, there is a question about the themes of what fields will undergo research and development. Professor Furukawa, what is being discussed in the International Technical Committee?

Furukawa: At the International Technical Committee, the so-called technical fields are called technical themes. A few discussions covered them during the Sydney meeting in February and they were fundamental concepts in Vancouver in July. Since Canada was the sponsoring country, Canadian committee members gathered in Vancouver and summarized the proposal and concepts for the first phase. We argued over telephones and faxes on what will be the technical themes proposed at the final technical committee meeting in December based on the proposal at that time.

While I can't give details at this time, I can slightly clarify why IMS involves the collaboration of three or more countries. Research themes needed in the collaboration of three of more countries are obvious. If the collaboration is between two companies or two countries, different methods are used. For three or more countries, as Mr. Ohno stated, we must know what the research issues are for industry that must be advanced when corporations, research laboratories, and universities participate. If the full-scale program is skillfully started, this probably becomes the most important decision standard. Although this is my personal view, actions involving multiple countries return in the end to global environmental problems that are currently a topic of discussion. I think it's dangerous to rush there immediately. Since this is a major barrier, it is important to have this as the axis. Since everyone in manufacturing industries works on environmental problems, what is the purpose for the participants working hard and taking risks. It is important for research themes centered on manufacturing industries to benefit the participants, participating countries, and people all over the world.

In this context, the six technical themes in the feasibility study proposed originally are without a doubt important areas. In addition, several fields requiring new international cooperation will appear.

Manufacturing Systems of the 21st Century

Chair: Today Mr. Ohno is the only participant from the private sector, so what fields in IMS interest the private sector in particular?

Ohno: As Professor Furukawa stated, the problem is what should be the future of manufacturing or the manufacturing industry. The expectation is the directions for finding solutions in the IMS project can evolve. Rather, everyone will discover them together. Since the manufacturing industry covers a broad range like electronics manufacturers like us, the automobile industry, the construction industry, and chemical plants. The common problems among them must be constricted to some degree. As the Professor stated, these will become the themes for this feasibility study.

When we consider the manufacturing industries of the 21st century, a variety of problems emerge. It's said this is the era of the paradigm shift. In these times, while giving substance to the spirit of the Kyoto statement, the manufacturing industry must carry out this shift. I would like to expect this to be a major guidepost. This means the benefits to humanity and society and the global environment are the backbone. Since these are surely newspaper headlines, we must consider what kind of technologies to have in order for these breakthroughs to be drawn out or invented. At this point, it is not clear to me, whether related leading technologies will be performed here or whether they will be gathered from other places and applied. I believe both ways are good. Each leading technology already exists at universities and research organizations, so academic meetings and work will center around each one. Our most important ideal is to create a mechanism to contribute to the development of humanity and society through our manufacturing industries.

These problems have been discussed a number of times before. Given these problems, how will the content of the program be created under this extraordinary vision? While 10 years has been suggested for the time period, I don't think these problems can be solved in 10 years. In fact, it's important to have a system as soon as possible, however, even while saying this, I don't see concrete results in three to five years.

In the companies, some amount of money and people must be allocated for this purpose. Therefore, a concrete program must be further clarified in order to persuade within the companies. I would like IMS to develop while making this compromise.

Chair: Thank you.

I can't explain it well, but every activity in the world is unusually global and we will dramatically change a few paradigms. A mechanism for collaborative research and development based on cooperation will be created and applied in the next century. This will be a major experiment this time, but if it is a success, not only manufacturing fields, but the concept of the IMS project will become the model for international collaborative research in other fields. This would be great and I expect it to happen.

As for the IMS Center, actions like the international feasibility study were introduced to a number of people

and the range of targets of the IMS project have widened. Through the participation of as many people as possible in the planning and international collaborative research and development, growth will occur.

Thank you very much for taking time from your busy schedules to be here today.

MITI Official on Mid-Term Technology Outlook for Machine Tools

94FE0296B Tokyo KIKAI SHINKO in Japanese Nov 93 pp 21-23

[Article by Tetsu Yasui, Industrial Machinery Division, Machinery and Information Industries, Ministry of International Trade and Industry (MITI)]

[Text] Japan's machine tools industry has undertaken the development and manufacture of products which have numerical control systems incorporated into the machines themselves and are generally superior in terms of costs, plays an important role in improving the efficiency of manufacturing systems, and has even established pre-eminent global competitive strength. While considering the international situation, a future step is to develop measures to address specific changing needs and to bring about technical innovation.

Trends in the Industrial Goods Industry

The industrial goods industry that supplies capital goods, such as advanced function products like semiconductors and electronic devices for industry, advanced machine parts or machine tools that require expertise, industrial robots, and semiconductor fabrication equipment, is expected to develop along with advances and improved efficiency in manufacturing technologies for essential industries and the growth of information, communication, and software systems industries not only in Japan but throughout the world. In addition, while overseas development in consumer goods assembly industry progresses, basically, an increase in the proportion of on-site self-subsistence is expected for parts and capital goods. While for advanced parts and capital goods that integrate advanced technology and expertise and software, activities are expected to continue in advanced manufacturing technologies for industrial property industry in Japan as domestic developments continue.

Accompanying this development, Japan's industrial economy is expected to continue to convert to a domestic demand-driven structure. Also, when future international development of Japan's industries is surveyed, advances in specialization by international product differentiation and strengthening of international cooperation between corporations are anticipated with advanced countries like the United States and European countries. However, mutually dependent relationships with the Asian region will proceed in investments and trade through the development of specialization between tasks and product specialization.

1. Outlook

While continuing to fundamentally rely on the demand of the consumer goods assembly industry that strengthened international competitiveness through mass production technology and supporting active facilities investment and manufacturing management, the industrial goods industry that supplies capital goods, such as advanced function parts like semiconductors and industrial electronic devices, machine parts and machine tools that require technical expertise, industrial robots, and semiconductor fabrication equipment, has advanced to this position by accumulating advanced techniques and technical skills, and supplying parts and capital goods of high quality and lower costs.

In the future, Japan's domestic industrial goods industry is expected to continue to evolve (1) to address Japan's industrial economy in terms of societal needs like conserving energy and preserving the environment, the supply of new advanced products and investments in new capital goods; (2) along with developments in the information, communication, and software systems industries, the demands of these fields are expected to increase; and (3) the need for capital goods investment and advanced function products that integrate advanced techniques, skills, and software will be fostered as overseas investments in the consumer goods assembly industry expands.

2. Issues

From the perspective of maintaining a foundation for intermediate development of Japan's industries, the industrial goods industry will seek to supply advanced parts and capital goods that will be required by the consumer goods industry in a short delivery period, with high quality, and at low costs.

In order to support creative innovation in Japan's industries, facilities needed to build prototypes and mass produce advanced parts for newly designed parts and suitable products are being sought. This role is anticipated in the industrial goods industry. To be able to respond to these kinds of high level demands, the intensification of technology must be planned.

Further, in response to environmental changes enveloping Japan's industrial economy and new societal needs, the industrial goods industry itself must earnestly develop advanced parts and equipment that integrate technology and software.

The industrial goods industry has often depended on expert technologies that have been accumulated, and this foundation must be strengthened. In the machine parts industry in particular, the manpower shortage, given the backdrop of the recent alienation of young people from manufacturing industries, is worrisome.

Expectations and Issues in Different Fields of the Industrial Goods Industry

1. Semiconductors

In the 1980s accompanying the developments in manufacturing technology and microfabrication technologies, Japan's semiconductor industry maintained strong competitive strength centered on memory. However, the rise of Korea in the memory field and actions to maintain competitive strength by the United States, which maintains strength in design and development, must be confronted.

Today, as equipment investment and R&D investment costs become formidable, investment efficiency worsens and risks increase. To distribute these risks and efficiently allocate economic resources, encouraging international collaborative relationships and taking actions to increase the added value of the products are expected. Additionally, an environment is expected to be provided to increase strength in unique design and development.

From now on, the manufacturing scale of semiconductor integrated circuits is expected to expand with advances in information technology. There are also fields where rapid increases in demand are anticipated because of progress in the practical application of memory that uses new technologies, like the rapid expansion of flash memory and the creation of a system on a chip where integration on the chip takes place at a level closer to the application level. These new fields will be energetically ventured into.

2. Industrial Machines

Previously, in the fields of various manufacturing equipment (industrial machines) such as machine tools and industrial robots, Japanese manufacturers endeavored to develop and manufacture products superior in cost and equipped with numerical control systems into the tool itself and played an important role in developing more efficient manufacturing systems, as well as establishing pre-eminent competitive strength worldwide.

To accomplish integrated technical development that includes operation software to advance the systematization of manufacturing technologies, not only manufacturers like industrial machine vendors (i.e., manufacturers of machine tools and industrial robots and engineering corporations), but each industrial user (i.e., automotive, appliance, steel and iron, chemical) must cooperate to surmount the conventional frames of industry types and build new manufacturing systems.

Technological power must be supported to continue to supply industrial machinery to address new problems confronting industry, such as investments in reducing labor to confront the manpower shortage and investments for environmental conservation.

Furthermore, in order to develop industries all over the world, it is important to supply hardware (machines) and software (people who are the guides) that support the industrial base.

3. Machine Parts

The machine parts industry is divided into (1) molding technology (metal dies and wooden molds), (2) parts processing (processing individual parts in the form of scrap, and iron and steel raw materials), and (3) parts assembly (individual parts are assembled in the assembly line). Until now, Japan's machine parts industry possessed these kinds of advanced parts processing function and supplied parts with high quality at low costs in short delivery periods for user manufacturing, and contributed to the establishment of competitive strength for the appropriate industries and maintaining the high functionality and reliability of the final products like automobiles and appliances.

In the future, Japan will supply advanced parts to foreign countries as the "third resource" following iron resources and energy resources. By moving parts assembly overseas, Japan can contribute to the development of the global economy. Since many parts processes create parts with high added values by using scrap, such as scrap iron and recycled aluminum alloys as the raw material, contributions to solving recycling problems are expected.

Also, by Japan's industries designing creative innovations, the wooden molds and metal dies for manufacturing prototypes or for mass producing newly designed products, and the supply of new products in a short time, with high quality, and at low costs are important. Support and development of the machine parts industry are envisioned.

On the other hand, to suitably address the difficulties of business succession like urbanization and problems with successors, in addition to the manpower shortage, environmental facilities and policies should probably be examined.

Technology Trends in Machine Tools

1. Environmental changes surrounding machine tools

When the machine tools industry is considered as one field of the industrial goods industry, the whole manufacturing industry that envelops machine tools is nearing a major technological turning point because of the following environmental changes.

(1) Compared to earlier systems, manufacturing systems will expand significantly.

(i) The target will not only include the factory line, but design, prototype manufacturing, and management fields.

(ii) Not only one business but multiple businesses, and not only manufacturing in Japan but in other countries must be targeted.

(2) Manufacturing systems will depend on simple mechanical systems to human factors, i.e. organizational

theory, the shortage of skilled workers and craftsmen, and the inheritance of knowledge.

(3) As for manufacturing systems, pursuing a comprehensive economy is required that includes pursuing conventional productivity to considering the environment and energy.

2. Technology trends in machine tools

Exact measures are being sought in the machine tools industry given the above environmental changes. From this viewpoint, the Ministry of International Trade and Industry is tackling the three major themes of R&D for manufacturing technology innovation, R&D on environment supporting manufacturing technology, and social systems technology.

(1) R&D for manufacturing technology innovation

Next generation manufacturing technology is represented by the Intelligent Manufacturing System (IMS) and micromachine technology. IMS is an international collaborative research program involving six countries and regions that will implement systems that integrate the whole manufacturing process at a high level and solve structural problems confronting manufacturing industries all over the world. Micromachine technology aims to develop micromachines that can perform precise and complex operations.

(2) R&D on environment supporting manufacturing technology

This involves R&D on the ecofactory and integrated recycling systems for cold waste material, low temperature crushing. The ecofactory implements R&D for disassembling complex products and for resmelting technology for the materials and is expected to build the backbone of a recycling society.

(3) Social systems technology

From the view of the objective of improving urban functions like distribution and municipal gas as represented in deep underground development technology, technical developments are implemented to construct a deep dome-shaped space.

IROFA Official on State of IMS Project

94FE0296C Tokyo KIKAI SHINKO in Japanese Nov 93 pp 24-32

[Article by Toshihiko Noumi, director of research and development, IMS Promotion Center, International Robotics and Factory Automation Center (IROFA)]

Introduction

IMS, which is the acronym for Intelligent Manufacturing System, is the manufacturing system planned for the 21st century. The systematic framework to execute R&D on the technologies required in IMS through international cooperation is called the IMS project.

The need for the IMS project was advocated by Japan. Because of its international impact, under the auspices of the two year plan that began in February 1992, IMS's international feasibility study was started by advanced countries. As one link in the study, six international collaborative research projects were implemented as the test cases. We are now approaching the final phase of the international feasibility study. Starting next year, the full-scale IMS project is expected to begin through international cooperation.

Based on this situation, I will present in this paper an overview of IMS and the IMS project and the current state of the international discussions.

Environmental Changes Surrounding Manufacturing Technology and IMS

Through advances in manufacturing technology, the economy has soundly developed and people's lives have been enriched. In this context, manufacturing can be thought of as the source of this wealth.

Even in recent years, manufacturing technologies have advanced based on the automation of machine tools, the introduction of robots, and the practical application of information and communications technologies. Moreover, improved manufacturability, improved quality and reliability, and advanced product functions were achieved.

However, if we envision what future manufacturing technology should be, various structural changes will evolve in the environment surrounding manufacturing. Even in manufacturing technologies, measures to address the following environmental changes are required.

1. Globalization of manufacturing

To preserve the manufacturing base in regions where demand exists and to avoid the risks of monetary exchange in the manufacturing industries in advanced industrialized countries, cases of crossing national boundaries and mutually expanding into the factory sites are increasing. In planning for total optimization to be comprehensively applied to the global bases of each company in development, manufacture, distribution, and sales flow of products, these kinds of systems must be flexible in response to social and economic changes.

2. Addressing global environmental problems

As global environmental problems worsen, manufacturing systems must possess energy and resource conservation. Therefore, besides energy conservation, resource conservation, and pollution measures in each factory, measures are needed that take a comprehensive perspective in view of the complete product life cycle from product manufacturing to consumption and disposal.

3. Market expansion and more advanced and diverse consumer needs

The business market of each country in the world extends into other countries and each business market is expanding into every region in the world. Therefore, from the perspective of product development and sales, consideration of the social and economic differences of each region of the world are being pursued. Moreover, because consumer needs are becoming more advanced and diverse in each market throughout the world, improved product functions and quality, lower costs, rapid development of new products, and multi-product, small quantity mass production must respond to consumer needs.

4. Changes in the labor market

A manufacturing system operates to unify man and machine. In response to the cultural and social circumstances of the regions where factories are located, man-machine systems must be built. In Japan, for example, to address the needs of workers seeking meaningful work and to address the alienation of young workers from manufacturing industries, dangerous, dirty, and demanding work is being mechanized and the role of human labor will be intellectual and humane. Because maintaining a skilled work force is difficult, technical skills need to be mechanized.

5. The appearance of "automated islands" in the manufacturing industry

To date, the results of advanced automation in each manufacturing process have not provided a satisfactory mechanical interface to manufacturing equipment and robots, thus leading to the appearance of *automated islands*. These circumstances also lead to the development of automation technologies by each vendor and user of manufacturing equipment. In the future, a comprehensive system will be built to include the sales and distribution division, the development and design division, and the planning division for business strategy based on each manufacturing process in a factory. Information must be applied and it must cross divisions.

To conquer these kinds of problems, the next-generation manufacturing system for the 21st century is a system that will design for the flexible integration and application of the total scope of business activities from the ordering to design, manufacture, and sales, and improve productivity while stimulating a variety of intellectual activities in the manufacturing industry and planning the fusion between intelligent machines and people. This is the Intelligent Manufacturing System.

Three Viewpoints of IMS Development

Since manufacturing technologies are the key to competitive strength in industry, independent developments in each corporation were treated as corporate secrets. Consequently, even manufacturing technologies had already lost their competitive significance to certain corporations, they were not conveyed as public knowledge and were often lost in product changes and manufacturing process changes. This kind of knowledge must be organized and systematized, and be put to practical use as a common foundation for training the next generation technical workers and for technological development.

The result of maintaining separate manufacturing technologies at each corporation is the machines and information specifications differed with each user and vendor. Thus, a major problem is building a comprehensive manufacturing system integrating independent manufacturing equipment and information systems.

Manufacturing technologies circulate through a pre-competitive phase that develops fundamental research, a phase where the competition between corporations is used, and a post-competitive phase in which the competitive significance of knowledge ends and it is shared in the industry. I believe there are many fields where cooperation not just competition between corporations is required.

From this perspective, the technological development of IMS must establish a common fundamental technology that will become an asset of mankind and in a unified manner (1) organize and systematize knowledge, (2) develop next-generation technology, and (3) promote standardization.

The IMS Development System

IMS Project

1. The importance of international collaborative research

IMS is an integrated system of all corporate activities in the manufacturing industry. This system will expand worldwide accompanying the globalization of corporate activities. The technology to realize IMS, however, cannot be independently developed by one user of the manufacturing system or each vendor of manufacturing equipment. Technological development must proceed under the vertical cooperation between industries, that is vendors and users, and the horizontal cooperation among vendors and among users. In addition, since the technical content must be basic research that involves innovation in basic ideas on building a manufacturing system, cooperation from not only the industrial world, but from the academic world is required.

Furthermore, cooperation is essential to tackle issues shared by manufacturing industries in advanced countries, like global environmental problems and the globalization of manufacturing.

That is, it is essential to (1) have mutual pooling of the technologies that are the forte of each advanced country to enable depth in the research content and advanced manufacturing technology development; (2) avoid the

duplication of investment of development resources due to each country promoting independent technological development; and (3) conduct international planning of the basic technologies for manufacturing systems in supplying the machines that form the manufacturing system among advanced countries and international industrial collaboration within the same industry. Therefore, international cooperation is a basic element in IMS technological development.

Given the above perspective, the IMS project, a next-generation manufacturing technology, must be implemented as an R&D program where the industrial and academic worlds of each advanced nation collaborate internationally.

2. Features of the IMS Project

Since the IMS project described above must proceed with widespread participation of the industrial and academic worlds in each advanced country, characteristic features are expected from the viewpoint of international collaboration in the R&D system. Today, a specific system has not been determined because international discussion is underway. However, the following features are present in the test cases currently being implemented experimentally.

(1) Widespread participation of advanced countries

Currently, the feasibility study of the IMS project has proceeded with the participation of a total of six regions of the United States, the European Community (EC), Japan, Canada, Australia, and the European Free Trade Association (EFTA is comprised of five countries). In this way, this program will become multiple projects through widespread participation of each advanced country.

(2) R&D by international consortia

Multiple R&D projects are implemented under the IMS project, but each project is implemented as an international consortium formed by the applicants from corporate, academic, and public research institutions in the six participating regions. In this kind of international consortium, the research direction of suitable R&D projects are studied by all of the participants. Each R&D problem of the project is assigned to a participant and the research is carried out. The result is more depth is given to the research content because of international studies.

Therefore, this is not the mere exchange of information on research results, but the participants in an international consortium contribute to their mutual wisdom and have the objective of international cooperation in a form that advances rapidly and is unified from the planning of R&D to the implementation.

(3) Independent theme selection

The R&D research is implemented led by the industrial world in the IMS project. As a result, R&D problems important to IMS are not assigned to each international consortium as research themes. The themes desired by each international consortium are independently selected from technological fields important to IMS, then the R&D project is planned.

(4) International research management

The R&D projects implemented under the IMS project are advertised and selections are made from submissions to the international consortium. After the selection, evaluations are performed. Research management such as selection and evaluation are carried out with international cooperation.

Consequently, one feature of the IMS project is international cooperation in research management, such as establishing international committees and cooperating among the regional secretariats.

(5) Funding responsibility by region

In the current test cases, the funding responsibility for R&D and research management is performed by each participant, although assistance through public funding in each participating region is expected. In relation to the test cases, assistance funds are spent from existing public funds in Japan and Europe, even in this case, the target for assistance is restricted to regional participants. The system adopted places the responsibility for funding in each region. Future funding responsibility is currently being studied and the idea of regional funding responsibility has a high probability of continuing.

(6) Forming rules on handling intellectual property rights

The handling of international property rights (IPR) must be agreed on beforehand when carrying out international collaborative research. Mutual agreements are determined beforehand among the participants in each international consortium. Further, the content of this agreement fulfills a few conditions of the IMS project. The most important one is the principle that the results obtained in collaborative research and intellectual property rights are royalty free to the participants in an international consortium. In this way, the realization of collaborative research is expected.

The Course of IMS Project Studies

1. Japan's proposal of the IMS project

The proposal was made in July 1989 at an FA vision meeting. Manufacturing technology evolving from FA to CIM must be developed in IMS for the 21st century Together with performing collaborative research of IMS technology through international cooperation, by systematizing and standardizing IMS technology and disseminating it worldwide, Japan demonstrated the need for international contributions.

Taking this opportunity to move towards realizing the IMS project concept in Japan, a study of the IMS

concept and content and a study of the project for this collaborative research were undertaken.

Japan compiled these results in the proposal for the IMS international collaborative research program in January, 1990, and then invited corporations and universities in the United States and Europe to participate in this program.

However, Europe and the United States were concerned about individual participation of corporations and universities in a program planned in Japan. Therefore, Japan, the United States, and Europe consulted one another on the necessity for the IMS project and what the IMS project should be.

2. Studies by trilateral meetings between Japan, the United States, and Europe

Based on the above situation, the management of the IMS project was examined by the Ministry of International Trade and Industry in Japan, the Department of Commerce in the United States, and the 13th Secretariat of the EC Committee in Europe and two trilateral meetings were held in May and November 1990.

In the trilateral meetings, agreements were reached by the three sides on issues such as the system for implementing the IMS project, technology development themes, intellectual property rights, and funding responsibility. Moreover, this became an opportunity to create a framework for international cooperation including not only research and development, but research management. Additionally, the international feasibility study is implemented before the full-scale IMS project. Canada, Australia, and EFTA agreed to participate in this feasibility study.

The Terms of Reference that stipulates the framework for implementing the international feasibility study was created in 1991. Preparations proceeded for the feasibility study such as the structure and decisions on the membership of international committees.

3. Preparing a domestic promotion system—Establishing the IMS Center

On 1 April 1990, the IMS Center was established as the core organization for promoting the IMS project in Japan in the International Robotics and Factory Automation Center (IROFA). The IMS Center is operated by membership fees (about ¥800 million) from 65 corporate members participating in R&D, and 17 supporting corporate members not participating in R&D but guaranteed the use of research results and offered information, trust money (¥180 million in 1993) and subsidies (¥930 million in 1993) from the government. Its functions include (1) to gather the opinions of the members about international discussions related to IMS and support MITI, (2) to promote IMS R&D by commissioning groups of core domestic members and academic members (researchers in the academic world cooperating in IMS's implementation), and (3) to survey technological trends related to these and devise ways to exchange information with organizations abroad.

To achieve this, each type of committee is being set up beginning with the promotion committee (chaired by Hiroyuki Yoshigawa, current president of the University of Tokyo) to implement (1) above in another secretariat in the IMS Center.

In the R&D area, along with performing advance surveys on five fields in 1990, advance research on about 20 themes have been implemented in Japan since 1991. Beginning in 1992, the targets were expanded in the R&D commissioned to groups participating in the international test cases that act as one link in international feasibility study. As a result, the R&D operating expenses for 1993 was about ¥1.6 billion.

Current State of the International Feasibility Study

1. Objectives and overview of the international feasibility study

The international feasibility study began in February 1992 and is expected to take two years in order to study IMS's international cooperation framework. Its implementation system places the International Technical Committee (ITC) for examining technical issues and the International Intellectual Property Rights Committee (IIPRC) for examining the management of intellectual property rights (IPR) under the International Steering Committee (ISC) which is the highest decision-making body. Representatives from industry, academia, and government from the six participating regions of Japan, the United States, the EC, Canada, Australia, and EFTA are participating as members.

The content of the international feasibility study is roughly divided into two parts.

The first is to examine the following four points for the future IMS project.

(1) System for implementing international cooperation like qualifications for participating in the program, and the structure and role of the committee

(2) Evaluation of the target technical fields and R&D projects, and selection standards

(3) Funding responsibility system

(4) Rules on managing intellectual property rights

The other part is to implement actual test cases as R&D projects by international consortia, accumulate experience on managing research, for instance, soliciting and selecting themes, and implementing R&D. These experiences will be reflected in studies on how the program should be conducted in the future.

The feasibility study is being promoted based on the following principles in this kind of international cooperation. The agreed upon items are (1) the benefits obtained from contributions and cooperation in international cooperation are equitably balanced, (2) the collaborative projects are related to industry, and (3) the results of collaborative research are shared.

2. International feasibility study schedule

The first year of the two year feasibility study is used primarily to examine the requirements for the test cases and to solicit and select projects. The second year is used to evaluate these test cases, examine the operation of the future program, and collect reports.

To introduce the general flow of the specific schedule, the study process and the future schedule in the International Steering Committee are given below.

Study Schedule of the International Steering Committee

February 24-25, 1992, Toronto—First International Steering Committee (ISC 1)

The decision to implement the feasibility study of the IMS project as follows:

- Participants: Japan, the United States, EC, EFTA, Australia, Canada
- Management organization: The International Steering Committee (ISC) is the highest decision-making body. The two committees of the International Technical Committee (ITC) and the International Intellectual Property Rights Committee (IIPRC) are established under it to undertake specialized studies.
- Duration: Two years (until February 1994)
- Based on the evaluations of the committees in the feasibility study, test cases are implemented as concrete international collaborative research projects.

July 20-21, 1992, Stockholm and Helsinki—Second International Steering Committee (ISC 2)

Adopt guidelines concerning technical issues of the test cases and intellectual property. Begin soliciting participants for the consortium involved in the test cases.

December 3-4, 1992, Venice—Third International Steering Committee (ISC 3)

Investigate the proposals of each international consortium to select the test cases that should be implemented.

January 26 and 29, 1993—Teleconference of representatives of the International Steering Committee

Final investigation carried out on proposed revisions to the test cases. Six test cases are selected.

April 5-6, 1993, Kyoto—Fourth International Steering Committee (ISC 4)

Interim reviews of test cases are already underway. Along with beginning studies related to the future IMS project, ITC members and IIPRC members are added to the task force set up in ISC to perform an in-depth study.

October 28-29, 1993, Canberra—Fifth International Steering Committee (ISC 5), scheduled

In-depth study of the future IMS project and study of the system were published in the final report and schedule.

January 25-26, 1994, Hawaii—Sixth International Steering Committee (ISC 6), scheduled

Final report published.

In this schedule the International Technical Committee (ITC) and International Intellectual Property Rights Committee (IIPRC) have already met five times and will meet once in December for a total of six meetings. Subgroups are set up in each committee and focused discussions are taking place.

3. Selection and implementation of test cases

When the International Steering Committee solicited test cases last July, applications were received from 11 international consortia. Six projects were selected as test cases by each international committee based on the results of examining the technical content, IPR agreement content, and consortium participants.

The themes were as follows:

(1) Clean manufacturing in the process industry (Japan, EC, EFTA, the United States, and Canada are participating.)

(2) Global concurrent engineering (Technology to build simultaneously and in parallel a product development and manufacturing system on a global scale. The EC, the United States, and Canada are participating.)

(3) Enterprise integration for global manufacturing toward the 21st century (Japan, EC, EFTA, the United States, Australia, and Canada are participating.)

(4) Holonic manufacturing systems (This is an autonomous, distributed manufacturing system. Japan, EC, EFTA, the United States, Australia, and Canada are participating.)

(5) Rapid product development (EC, the United States, Australia, and Canada are participating.)

(6) Knowledge systematization: configuration system for design and manufacturing (Japan, EC, EFTA, the United States, and Canada are participating.)

The number of corporations, universities, and public research institutes participating in the six test cases totals about 140; this demonstrates that international interest in IMS is high.

These projects launched R&D after final selections were made in January of this year and intra-regional (within

each country) and inter-regional (international) cooperation will continue to be developed through meetings and the allocation of tasks in all of the consortia. Each consortium deepens the research content by becoming an organization consisting of participating organizations, like corporations and universities, that are organizationally and culturally diverse. To enable each international research collaboration to continue in the future between participating researchers, expectations are high for implementing the future program.

4. Directions of discussions on the future program

Since international test cases were selected in January of this year, full-fledged discussions on how the future program should be implemented took place after the 4th International Steering Committee held this April in Kyoto.

The Kyoto statement included the following:

- Actions must address common international problems related to manufacturing.
- Final recommendations on full-scale research will be released early in 1994. And based on these recommendations, decisions are expected on the participation of each region in the full-scale program.

The recommendations in the Kyoto statement will become one part of the final scheduled report of the feasibility study to be compiled at the 6th International Steering Committee to be held next year at the end of January. During the period remaining until the end of January, the task of collecting the opinions of each region (each country) on the issues of the system for implementing the future program and technical themes will be energetically carried out.

To do this, subgroups will be set up in each international committee of ISC, ITC, and IIPRC to focus on discussing special issues. The current situation is opinions are being exchanged internationally by fax between these groups.

Because the opinions of each country are very constructive, the specific content of the future program is not determined, but improvements are added to the test case strategy and the strategy that produces results from international collaborative research is expected to be built without posing any obstacles.

Future Development of the IMS Project

In the final scheduled report of the international feasibility study to be compiled in January next year, the report will include the results of the study of specific content related to how the IMS project should be executed and the recommendations on how that kind of program should be carried out with international cooperation.

In each region (each country) that receives this report, final decisions will be made by the appropriate parties concerned with implementing the IMS project.

Later, as during the test case, R&D projects will be solicited and selected by the international consortia and full-scale R&D on international IMS will begin.

The six cases currently underway are expected to become full-scale projects. In addition to the test cases, new R&D projects will gradually be selected. It is possible that new participants will be added to the structure of the international consortium of each test case.

In this context, even Japanese corporations and universities are expected to actively participate in the full-scale collaborative research of the IMS project by (1) moving to the full-scale R&D projects of the four test cases in which Japan is participating, (2) new participation in two test cases in which Japan is not participating, (3) moving domestic advanced research that have been underway to international projects, and (4) participating in new R&D projects proposed by other countries.

A great deal of time was required to create an international framework because the IMS project will become an international collaboration that involves more international research cooperation than before in the planning and allotment of tasks in R&D by international consortia, and international cooperation will be up to research management on theme selection and evaluation. However, as described earlier, next year's situation is expected to become the implementation of full-scale international research cooperation. The result of the efforts of many people from all over the world over a long time is now beginning to be realized.

Patent Office Official on IMS Intellectual Property Rights Guidelines

94FE0296D Tokyo KIKAI SHINKO in Japanese Nov 93 pp 33-38

[Article by Naoya Oku, Third Import Inspection Department, Patent Office, Ministry of International Trade and Industry (MITI)]

[Text]

Introduction

Over the 110 years since the signing of the Paris Convention for the Protection of Industrial Property, international protection of industrial property rights has basically been governed by the Paris Convention. The possession, protection, and use of inventions that will result from IMS projects were studied founded on the basic ideas of the Paris Convention of (1) the principle of the equality of one's own nationals and the nationals of other countries, (2) the first-to-claim system, and (3) the independence of the patents of each country. The Intellectual Property Rights (IPR) guidelines were adopted for minimum guidance. The IPR guidelines are the international IPR guidelines in the R&D test cases adopted for use in previous test cases. Currently, reviews are underway to create IPR guidelines for the full-scale program slated to start in the fall of 1994. However,

there are no other examples for establishing guidelines related to IPR protection in multiple international collaborative research. As the internationalization of collaborative research progresses not only in the manufacturing industry but in a variety of fields, lessons are being learned on the increasing importance of protecting intellectual property rights and an outline of IPR guidelines will be presented for future reference.

The Path to Adopting IPR Guidelines

1. Previous protection of intellectual property rights in international collaborative research

Obvious examples of international collaborative R&D are in Europe. For example, there are the EUREKA program, ESPRIT (European Strategic Program for Research and Development in Information Technology), RACE (Research on Advanced Communication in Europe), and BRITE (Basic Research on Industrial Technology in Europe). In Japan, there is the example of the International Superconductivity Technology Center.

The results of the EUREKA and ESPRIT programs are owned by the participating corporations or research institutes involved in the collaborative research. The government of each country that provided supporting funds and the EC committee do not own the results. In addition, ownership is determined by contracts between participants in collaborative research.

As for managing R&D results when the EC provides R&D supporting funds to corporations, the provisions are altered in various ways at the start of R&D by the EC committee and the corporations, but the EC committee officially published a standard contract model and is promoting its practical use.

On the other hand, the research results of the International Superconductivity Technology Center were all owned by the Center or the Center owned 50 percent and the corporation employing the researchers owned 50 percent.

2. Point of view of a study on creating basic principles related to IMS results

Before the IPR guidelines were created to manage the results of IMS, basic principles from each position were proposed. The following are points that must be studied as the basic principles Japan must emphasize concerning intellectual property rights that arise in the IMS project.

(1) The ownership of rights related to IMS research results, including the know-how, shall be decided while respecting the extent of the contribution by the researchers.

(2) The registration and protection of rights shall be in accordance with laws established with respect to the nature of the rights.

(3) By guaranteeing inventor's rights, preferential access of IMS research results immediately after development shall be possible. In addition, access to research results by people not participating in IMS shall be guaranteed.

(4) IMS research results, with the exception of know-how, shall be widely disseminated with suitable timing.

3. Comparison with the EC's plan

In creating IPR guidelines for managing IMS research results, the basic principles proposed by Japan are based on the viewpoint expressed in section 2. International collaborative R&D proposed in Europe, specifically, the EC, and the major differences are given below. These differences have been satisfactorily studied for creating and adopting the IPR guidelines.

(1) Concerning the rights of people who own a share of the results, agreement from other owners is obtained in the Japanese plan and licenses for third parties can be approved. In the EC plan, if "Make use as its own" is included in the approval of licenses for third parties, it violates Clause 73, Item 3 of the Patent Act.

(2) Concerning the implementation of the results, participants in the same consortium in the Japanese plan are given the royalty-free licenses only when there are no special procedures. While in the EC plan, licenses are given royalty free to parties who have made significant contributions to the project. However, there is the problem of balancing participants in the same consortium. Additionally, when business interests conflict for project participants, consent for licenses can be rejected.

(3) Related to the implementation of results in the R&D objectives, Clause 69 of the Patent Act, which states "The validity of patent rights does not extend to the implementation of patent inventions for experiments or research," was not based on a special stipulation in the Japanese plan. While in the EC plan, royalty-free licenses are granted to participants in the same consortium. Although this is not a point of contention, licensing fees are applied to project participants outside the same consortium. Conflict arises in the Japanese situation where royalty-free licensing is available even to non-participants. Similar to the stipulation in (2), even consent to project participants for licensing can be rejected when there is a conflict with major business interests.

(4) The Japanese plan does not contain any specific provisions to manage existing information. The EC plan stipulates permission for usage under the scope and range agreed upon in the consortium.

(5) To protect the results, when the application rights were waived in the EC plan, the application rights can be protected if a participant participates in all of the appropriate research activities. Namely, ownership itself is changed.

(6) To establish a committee to manage disputes and results, the Japanese plan proposed establishing one in

each region. The EC plan did not specify anything in particular and is based on meetings between concerned parties.

4. The path to create IPR guidelines

IPR guidelines will be devised after adequate studies and negotiations on the basic principles proposed by Japan, the EC, and the United States. The draft is based on the proposal from Japan. Examination of this draft proceeded in the International Intellectual Property Rights Committee. The first IIPRC meeting (held June 1991 in Tokyo) gathered the opinions from each region. The second IIPRC (held July 1992 in Brussels) saw the tentative completion of the "International Cooperation in Advanced Manufacturing IPR Guidelines for R&D Test Cases during the Feasibility Study."

The members of the IIPRC from each region are listed below.

International Intellectual Property Rights Committee Roster

(Australia) Mr. Paul Armarego, head public prosecutor, Ministry of Justice; Ms. Karen Bradshaw, AOTC lawyer; Dr. Terry Harders, CSIRO

(Canada) Mr. Robert A. Ferchat, CEO, Canada Nuclear Power; Dr. Arthur Catry, professor, Waterloo University; Mr. Stuart C. McCormack, lawyer, Stikeman Elliot Law Firm

(Europe) Mr. Anthony Parry, British Aerospace executive (UK); Mr. Gunnar Boman, director and lawyer, NUTEK (Sweden); Mr. Jacques Bus, EC secretariat (Belgium); Mr. M. Colombe, Bull S.A. (France); Dr. C. De Meyer, De Bandt, Van Heck (Belgium); Mr. Markku Lamola, EFTA secretariat; Mr. M. Lehman, Max Planck Institute (Germany); Mr. Rudolph Mueller, patent licensing manager and lawyer, Siemens AG (Germany); Mr. Paolo Sani, patent and trademark licensing manager, Fiat (Italy)

(Japan) Akira Ookawa, Patent Harmonization Legal Bureau; Hideo Doi, Mitsubishi Denki Ltd.; Katsuhiko Umehara, Ministry of International Trade and Industry (Shuuichi Okada attended the 2nd, 3rd, and 4th meetings, Hidehiko Nishiyama attended the 1st meeting)

(United States) Mr. Robert E. Falstad, lawyer, SEMATECH legal consultant; Sheryl A. Clark, lawyer, Buchanan Ingersoll Law Firm; Mr. Richard Donaldson, Texas Instruments Inc.

Overview and Features of IPR Guidelines

At the International Steering Committee (ISC) held in Stockholm and Helsinki on 20-21 July 1992, international IPR guidelines were adopted on handling industrial property rights for collaborative research on models and technology for next generation manufacturing processes from an international standpoint.

The guidelines introduced here are for the test cases that began in February 1993. Their formal title is "International Cooperation in Advanced Manufacturing IPR Guidelines for R&D Test Cases During the Feasibility Study."

Each consortium that participated in the test cases entered into the Cooperation Agreement of the consortium in accordance with the guidelines.

The guidelines consist of a preface, foreword, and nine chapters, 1 through 9. Next, an overview is given.

First, the preface clearly sets forth the minimal conditions that the IPR guidelines can apply to IMS test cases. Partners in the test cases can agree among themselves about additional provisions within the scope of satisfying these minimal conditions.

The foreword describes commissioning the International Intellectual Property Rights Committee to create the guidelines in the Terms of Reference (determining the basic framework such as participants at that start of the feasibility study, the management system, and the schedule proposed by the United States). The content of the cooperation agreement between partners and groups participating in R&D test cases implemented in the feasibility study must clearly follow the guidelines. Since this is based on the Terms of Reference, there must be assistance so that the contributions to international cooperation in IMS and the gains obtained from the cooperation are equitable and balanced. The end of the foreword mentions that this guideline applies experience gained in the test cases to establish IPR guidelines for full-scale research after the feasibility study and the possibility of additional changes remains.

Next, chapter 1, "Definitions," gives the definitions of the 16 major terms used in the guidelines. The major terms include *consortium*, *affiliate*, *foreground*, *background*, and *commercial right*. Particularly significant is the use of the terms foreground and background. The definition given for foreground means all of the information initially created or gathered in the project activity process and all of the intellectual property rights that directly arise from the project. Background means already existing information and rights. This expression is partly used in relation to managing research results in model contracts in collaborative R&D announced by the EC committee on 1 October 1988.

Another definition to be noted is affiliate. This is usually a subsidiary, a corporation that is directly or indirectly owned or controlled by a partner able to participate in this project. However, a corporation jointly owned or controlled by the government is not an affiliate.

In chapter 2, "The Ownership of Rights," foreground is owned by the sole partner that created it or by the collaboration partners. Furthermore, even when a project is organized with government participation or assistance and loans from the government, partners

guarantee the ownership of rights in accordance with the guidelines. Therefore, the ownership of background rights does not affect the project.

Chapter 3, "Summary and Report," shows that the IMS project is in no way closed. Except for special cases, the announcement of all project results must be approved by all the partners participating in the project. Additionally, a project summary is presented to all of the other project partners and to each IMS international committee. When the project ends, the summary of the results obtained from the project are compiled in a report and published.

In chapter 4, "Research and Development," the royalty-free licensing of R&D objectives related to a partner's foreground is guaranteed. (The EC plan where other partners in the consortium are compensated was excluded.) Here the most notable point, however, is background information, which falls within the scope agreed on by the project partners in accordance with the conditions agreed on by appropriate partners, must be offered in the consortium for R&D objectives for the project. Also, another point is licensing for background rights must be performed in a similar manner. This description is the point that makes the partners the most nervous about the provisions in the following chapter 5.

The possibility of rejecting permission for licensing rights when there is a business interest conflict, that was in the EC proposal, accurately represents the participants' feelings.

In chapter 5, "Commercial Rights," similar to chapter 4, each partner obtains the foreground of other partners royalty free and financially equal commercial rights. The financial equality which differs from chapter 4 reflected the Japanese view. A licensing fee that must be paid to the country when a national research institute participated is assumed.

One notable point in this chapter is project partners must give permission for background rights in accordance with the formal commercial conditions when reasonably necessary in order for other partners to have foreground commercial rights. Related to commercial licensing in particular, a provision stricter than "within the scope agreed on by the project partners and in accordance with the conditions agreed on by appropriate partners" for implementing the previous R&D objectives does not exist and permission cannot be refused.

In chapter 6, "Permission," a partner that independently owns foreground can grant licensing permission to third parties. Moreover, partners who jointly own foreground can grant foreground licenses to third parties in accordance with the mutual understanding of the cooperation agreements among partners. (This point is coordinated with clause 73, item 3 of the Japanese Patent Act.) The partners of other projects are given permission under advantageous conditions.

In chapter 7, "Protecting Licenses and Rules for Maintaining Secrecy," first, partners owning foreground information must take the appropriate measures to guarantee legal protection. All of the other partners are notified of the situation together with an overview of the invention. When legal protection is not sought, other partners in the same project under mutually agreed on conditions can guarantee protection. Even if there are partners who waive their application rights and do not participate in all the appropriate research activities, the EC plan that can guarantee application rights is moved away from and application rights are limited to partners in the same project.

In maintaining secrecy, a partner having rational procedures equivalent to the procedure devised for the confidential information it owns must make effort to maintain the secrecy of confidential information obtained in the project. This information is not restricted when made public regardless of the partner's own responsibility.

In chapter 8, "Conflict Resolution Methods and Applicable Laws," methods to resolve conflicts arising about the interpretation or application of these guideline are determined. The method first seeks a friendly settlement, but when this is not possible, non-binding arbitration of the International Steering Committee is sought. Then, the conflict resolution method is agreed upon in each cooperation agreement and is responsible for agreeing on which laws (which country's laws) apply in the agreement.

Finally, in chapter 9, "Cooperation Agreements," partners conclude in writing cooperation agreements that conform to one or multiple guidelines that manage participation in the project.

IPR Guideline Problems

IPR guidelines were adopted for use in previous test cases. Currently, reviews are underway to create IPR guidelines for the full-scale program slated to start in the fall of 1994.

Reviews continued in the 3rd International IPR Committee meeting (Dallas), the 4th meeting (Sydney), and the 5th meeting (Vancouver) and the evaluation of coordination of the cooperation agreement decided on in each consortium was sufficiently discussed. During the review process, the following problems were identified in the IPR guidelines.

Background

In the background, there are problems in offering background to partners. For example, when specialized licensing rights are already established with third parties outside the consortium for patents related to background or when they are shared, it is not possible to offer existing background to consortium partners. The above

points are not stipulated in the current guidelines. Therefore, corporations and research institutes who want to participate in the IMS project will not be able to participate because of the fear of not being able to fulfill the obligation of providing background.

To eliminate these kinds of non-partners, new guidelines must be created to stipulate the establishment and ownership of special enforcement rights.

Managing studies

How to manage projects that center on gathering information and not carrying out full-scale research tasks is under study. When only information is collected, usually, foreground will not arise, so it does not have to be completely constrained by IPR guidelines. Thus, only required provisions in the IPR guideline need to be applied.

Compulsory strength of the guidelines

Discussions have taken place while the guidelines were being created on whether the guidelines should be compulsory or to consider the provisions simply as recommendations.

Currently, based on the recommendations of the guidelines, a collaborative research cooperative agreement is being developed on the items agreed on in each consortium. There is also the view that the method should state confirmed items in detail.

While international collaborative research is promoted, the minimal conditions must clearly establish which common rules are compulsory, then each consortium will observe them. As for items not covered in the guidelines, an agreement is made for each item and is covered in the agreement. This work will proceed based on this idea in future revisions of the guidelines.

When the guidelines are compulsory, the following problem arises on which provisions will be compulsory. Studies on this are continuing and it is still unclear.

Research announcements of research institutes

When research is announced, it is not done freely, but must be agreed on by the other partners. Dissatisfaction will arise concerning the inability of nonprofit research institutes to officially announce results. Therefore, as a condition for procedures concerning the protection of its own research results, a method to give rights to announce and disclose information is considered acceptable.

New Partners

The handling of new partners remains undecided. Currently, there are only six countries and regions, but other countries are expressing a desire to participate in the collaboration. Studies are needed on how this should proceed. However, this problem extends beyond a simple guideline problem. It is a problem of the whole IMS project. The guidelines will be revised following the direction of decisions made by the International Steering Committee.

The relationship to the Antimonopoly Act

When there are competitive relationships between businesses in products that are R&D targets of collaborative R&D, a study of antimonopoly law is needed from the perspective of unfair trade restrictions. That is, by implementing this kind of collaborative R&D, when competition in a definite trade arena of some product is restricted in essence, the R&D itself violates provisions of the Antimonopoly Act. Issues for study arose in this project concerning this point. However, at this time, specific items that violate the provisions of the Antimonopoly Act are not known. International collaborative R&D like the IMS project does not monopolize results and does not prevent the general dissemination of technology. Thus, the opinion is there are no problems with the Antimonopoly Act.

The Future

Opinions are being exchanged between the regions that should advance current revisions on the above problems. In the future, intermediate plans will be summarized. Finally, at the 6th International IPR Committee held in Vienna in December 1993, the final draft of the revised IPR guidelines for the full-scale program is expected to be completed.

Micromachine Center Official on Micromachine Technology R&D

94FE0296E Tokyo KIKAI SHINKO in Japanese Nov 93 pp 39-48

[Article by Takayuki Tsunemi, managing director, Micromachine Center]

[Text]

Introduction

When micromachine technology is systematically established, various micromachine systems will be implemented to carry out advanced tasks in extremely narrow spaces. These kinds of systems are expected to be used in a wide range of fields beginning with plant maintenance and medical treatment.

To realize these technologies, in addition to processing and assembly technologies for miniature actuators and moving mechanisms and system technology, scientific and technological research to explain physical and chemical phenomena in the micro domain are necessary. In addition to being very risky and costly, this R&D requires a long period of time.

Therefore, at the Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI), R&D on micromachine technology was

selected as one R&D project in the Industrial Science and Technology Frontier Program.

Approval was granted to establish the Micromachine Center in MITI as the main organization to promote the civilian side of the project. In addition to this R&D, work such as research on the basic technologies needed to establish a micromachine technology system, standardization, and promoting the dissemination of the technologies will be carried out.

Overview of Micromachine Technology R&D

1. R&D objectives

To cope with the highly advanced and difficult state of maintenance accompanying more advanced, precise, and complex manufacturing systems and to realize superior medical treatment for people, the need for micromachines to be able to perform finely tuned and complex tasks is increasing.

To this end, based in the Industrial Science and Technology Frontier Program of the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI), R&D on micromachines is underway to diagnose, treat, test, and heal in restricted spaces for instance, inside a living body or pipes in a plant in order to repair a variety of complex machines like electrical generators and also to do little harm to the body during diagnosis and surgery in medical treatment.

The R&D is divided into a first phase from 1991 to 1995 and a second phase. The basic development plan for both have been decided.

Basic plan for phase 1

(1) R&D phase: 1991-1995 (Total plan is 10 years long.)

(2) Total R&D funds: ¥ 10 billion (The total funding is ¥ 25 billion.)

(3) R&D objectives and methodology

The final objective is to realize technology for micromachine systems constructed from miniature functional elements that will move in the limited spaces inside the human body and in complex machines like power generation facility and autonomously perform high-level tasks. In phase 1, until 1995, the following technologies will be developed as the basic structural elements of micromachines. (Table 1 gives the R&D schedule.)

(a) Micro functional element technology R&D—Centered on experimental research, R&D on design, manufacturing technologies, and drive and control technologies for the basic functional elements that will comprise a micromachine like intelligence, environment recognition function, and mobility and propulsion functions

(b) Energy supply technology R&D—R&D on technology for generating energy inside micromachines and technology to supply energy

(c) System control technology R&D—R&D using research and prototype models related to micromachine information processing technology, communication technology, and remote and distributed control technologies

(d) Evaluation technology R&D—R&D on technologies to measure, monitor, and evaluate the characteristics of the micro functional elements

(e) Total system research—Research on the total micromachine system to clarify the total system of micromachine and study effective practical uses.

The R&D described above is promoted by the system illustrated in Figure 1 [not reproduced].

Table 1. R&D Schedule

R&D Topic/Year		Phase 1		Phase 2	
Microcapsule R&D	Research	Experimental and exploratory research	Mid-term evaluation	Advanced demonstration research	
Mothership machine R&D		Experimental and exploratory research		Advanced demonstration research	
Wireless inspection module R&D		Experimental and exploratory research		Advanced demonstration research	
Wired operation module R&D		Experimental and exploratory research		Advanced demonstration research	
Total system research		Research		Research	

Table 1. R&D Schedule

R&D Topic/Year		Phase 1		Phase 2	
Overview	Survey of technologies related to micromachines	R&D is performed on techniques and methodologies in the primary technologies required in the four types of micromachines (micro capsule, mothership machine, wireless inspection module, wired operation module). Surveys of the needs, overall system design, and feasibility study on power generator maintenance are performed.		Improving the techniques and methodologies with confirmed possibilities of implementation in phase 1 and systematizing micromachine technology is planned.	

2. Industrial Science and Technology Frontier Program R&D

(1) Highly functional maintenance technology development for power generation facility

In R&D on micromachine technology, primarily microfabrication technology, and the prototype manufacturing of various micro functional elements based on this technology are progressing. Basic technology is beginning on tribology in a micro environment, heat transfer engineering, micro science and technology in fluid mechanics, materials technology, design technology, measurement and evaluation technology, and control technology.

This project performs R&D to implement highly functional maintenance systems for micromachine technology for testing and repairing abnormal situations such as internally generated cracks without disassembling the heat exchanger of a pipe system in a generator. However, the history of micromachine technology is relatively brief and many problems exist that must be addressed in basic research. Therefore, while envisioning the implementation of highly advanced maintenance systems, the R&D objectives of this project are placed on establishing a micromachine technology system. Confirmation of the ability to implement the various techniques and methodologies needed to establish technical systems by the end of 1995 will be either experimental or theoretical.

Since problems that cannot be addressed by simply extending conventional technology are mounting up in the implementation of this project and technical R&D based on new perspectives is being pursued, the following points must be carefully considered.

(a) Dimension—The target dimension range is suitable for measuring the size of functional element parts in micromachine technology. The sizes of these functional element parts are set at the μm level as dimensions capable of creating arbitrary shapes using the micro processing techniques of IC processes and micro electric discharge processing methods.

(b) Micro environment—As the dimensions of the functional element parts enter the μm level, problems like surface tension, viscosity, tribology, and contamination differ drastically from the case of conventional mechanical systems. Mechanical systems based on new concepts that include new control systems and can be applied to phenomena characteristic of a micro environment are required. Therefore, molecular theory considerations become important. Further, characteristic problems of micromachines like measurement methods for minute physical quantities in the measurement and evaluation methods, and the effect of the grain diameter of polycrystalline material and anisotropic mechanical characteristics of simple crystalline materials are introduced.

Target R&D technology

To realize the micromachine technology system needed to implement a highly functional maintenance system for power generation facilities, the idea of a total system constructed from the four subsystems of the microcapsule, mothership machine, wireless inspection module, and wired operation module is envisioned in the basic technology, functional element technology, and system technology that form this technological system. Devices are needed to construct these modules. Thus, R&D will be conducted on principal micromachine technologies such as the needed micro function element technology, energy supply technology, control technology, and processing and assembly technologies (Tables 1-3).

As illustrated in Table 3, in each R&D problem the attainable R&D objective in phase 1 of this project is to increase the possibility of implementing the techniques and methodologies needed in each structural device as the principal micromachine technologies. Understanding the R&D results in the first phase is accomplished by methods that verify the possibility of implementation as a principal micromachine technology.

Table 2. R&D Issues

		Microcapsule	Mothership Machine	Wireless Inspection Module	Wired Operation Module
Energy supply technology		Power generating device	Battery device	Light energy conversion device, microwave energy conversion device	Solar power conversion device
Micromachine functional elements	Actuator mechanism technology	Steering device drive and suspension	Drive device, clamp device, coupling device, artificial muscle	Flexible, mobile device, voltage drive device	Traveling device, manipulator with multiple degrees of freedom, extension and contraction mechanism device, hydraulic device, fluid drive device, solar drive operation device
	Sensor technology	Wound detection device, position detection device	Recognition device	Ultrasonic wave device, CCD micro camera device, wideband light analysis device	Internal visual discrimination device
	Misc.	Signal generation device		Function coupling device	
Control technology			Holonic mechanism, behavior control	Communication control	

R&D examples

The research involved (1) microcapsule R&D, (2) mothership machine R&D, (3) wireless inspection module, (4) wired operation module R&D, and (5) total system research advanced fundamental studies on micro-sized electrostatic motor, torque measurement, prototype manufacturing of shape memory alloy micro coils, and solar power generation and booster mechanisms for energy supply.

As for static actuators, along with creating prototypes of basic elements, miniature torque measurement devices were developed and the characteristics of prototype actuators were evaluated.

(i) Figure 4 [not reproduced] is a conceptual diagram of a prototype radial gap electrostatic actuator.

(ii) In micro coiling technology, preliminary studies of shape memory alloys (SMA) took the form of studies of the micro coiling technology of Ni-Ti system SMA wires. Figure 5 [not reproduced] shows a photograph of a heat-processed wound coil spring with a length of 50 μm, an external diameter of 0.6mm, and the effective length of 20mm after forming the coil shape.

(iii) In solar power generation and booster mechanisms, the main objective is basic research on very efficient solar electricity generation which is derived externally. Photocells were simulated, fabricated, and evaluated. Studies were carried out on the basic technology for highly efficient micro transformers (Figures 7 and 8 [not reproduced]).

(iv) In supplying solar energy, the results of studies and basic research on the research objective of extracting the technical problems of solar generation elements like the solar batteries used in wireless inspection modules demonstrated the importance of improved processing of finely processed edges to suppress current leaks through edges processed in miniaturized solar power generating elements and the importance of a heat radiation structure to control the increased temperatures caused by incident light (see Figure 6 [not reproduced]).

Table 3. R&D Objectives

R&D Problem	Phase 1 Objectives	Phase 2 Objectives
Microcapsule R&D	Verify the possibility of implementing the techniques and methodologies of the principal micromachine technologies needed in micro power generators, signal oscillation mechanisms, steering mechanisms, wound detection, position detection, drives, and suspensions	Plans to achieve improvements in the principal micromachine technology developed in the first phase and to systematize micromachine technology
Mothership machine R&D	Verify the possibility of implementing the techniques and methodologies of the principal micromachine technologies needed in main body drive mechanisms, micro optical mechanisms, coupling mechanisms, clamp mechanisms, artificial muscles, microbatteries, group control, and behavior control	
Wireless inspection module R&D	Verify the possibility of implementing the techniques and methodologies of the principal micromachine technologies needed in flexible mobile mechanisms, micro CCD mechanisms, function coupling, micro light analysis, solar energy supply, and cooperative control	
Wired operation module R&D	Verify the possibility of implementing the techniques and methodologies of the principal micromachine technologies needed in tube-shaped manipulators, optical driver operation mechanisms, mobility and operating mechanisms, solar power generation and booster mechanisms, environment recognition mechanisms, and high output power sources	
Total system research	Based on R&D and survey results, develop the conceptual design and feasibility study for a micromachine system for use in power generation facilities and study the implementation of the maintenance system	

(3) R&D on micromachine technology for medical treatment

Another field considered to be a target application for micromachine technology is the medical field.

In medical treatment, especially diagnostic techniques, advanced and less invasive methods are sought. In other words, if micromachine technology is applied to medical therapy, the treatment devices will be more compact and multifunctional and will implement accurate minimally invasive medical treatment needed in advanced medical treatment which is not possible with conventional technology. This will affect efforts to save patients' lives, shorten the treatment period, and prevent complications.

In the application of micromachine technology to manufacturing fields, research on micro technology is underway in a wide range of areas from element technologies like existing sensors and actuators to the device level technologies to integrate these elements. To apply these technologies to the medical field, devices must be miniaturized for the miniature environment and unique phenomena in a living body. The problems that must be solved to achieve this become the R&D micromachine technologies that consider medical application.

In this context, the application of micromachine technology in medicine is envisioned in this project. The objective is to develop various micromachine element technologies that will build this system. The following points are noted in advancing this project so that it can be implemented in medical applications.

(a) Living body environment—When artificial materials are used in direct contact with a living body, various levels of reactions to foreign materials occur at the boundary between the material and the living body. This must be avoided and, at the same time, the devices must synchronize with the specific system in the living body. That is, for the micromachine to support these functions in the blood, in organs, and in tissue, research is needed on methods to avoid the recognition of foreign material like thrombosis reactions in the blood, and inflammation reactions and immunity in hard and soft tissues in the body. In addition, since disinfection and sterilization are performed, microstructures and materials must be introduced that can withstand these kinds of environments.

(b) Micro environment—When the dimensions of functional element parts reach the μm level, problems with surface tension, viscosity, and frictional force differ significantly from those in existing medical systems. Consequently, peculiar phenomena in the micro environment must be addressed by mechanical systems based on new concepts, including new control techniques. Therefore, studies are required on molecular theory considerations, measurement and evaluation methods for minute physical quantities, the effect of the grain size of the polycrystalline material, and the anisotropy of simple crystal mechanical characteristics.

(c) Precision—As the dimensions of functional element parts become smaller, ways are sought to ameliorate shape errors and surface coarseness corresponding to this.

Target R&D technology

In phase 1, micromachine element technology in medical treatment systems and diagnosis inside the body, beginning with blood vessels in the brain, are expected. R&D will proceed on the following three technologies which are rich in generality.

(a) Laser diagnosis and treatment technologies—The laser is one of the most promising technologies for diagnostic and therapeutic techniques. If energy transmission and optical signal detection are simultaneously possible in ultraminiature diameter optical fibers, lasers are expected to be applied to many regions.

(b) Micro touch sensing technology—Miniaturizing touch and pressure sensors and eliminating wires from sensor drives and signal lines that consider the flexibility, viscosity, and elasticity of barriers and organs in a living body are essential technologies for narrow catheters and microsurgery.

(c) Blood pressure and blood flow sensing technology—Technology that is reflected in fields where blood pressure and flow are detected by micro sensors and diagnosis and therapy will be an important element technology of catheters for blood vessels and can be applied to sense other fluids.

Research will also begin on balloon tube mechanisms and micro nozzles. Also, as applications of industrial technologies to medicine, studies will begin on applications to micro catheters of the element technologies for diagnosing and treating cerebral blood vessels of ultrasound diagnosis, micro endoscopes, micro expansion and contraction mechanisms, and micro pumps.

It is difficult to determine precise technical objectives and evaluation methods when research is just beginning for the three issues being emphasized which all have a strong pioneering nature. Therefore, experimental research, which includes the exploratory research and making prototypes, is performed. To correctly understand the technical issues uncovered during this process, the objective standards and verification methods of the research results of important issues in phase 1 in 1993 are established.

3. Exploratory research on basic technologies related to micromachine systems

Micromachine technology is added to the scholarly fields of various technologies and sciences like mechanical engineering, electronic engineering, biology, physics, and chemistry. Since the history of this technology is brief, fundamental technologies like microphysics (i.e., tribology and mechanics in minute regions) that forms the basis for realizing the system technology, basic technology like materials technology (for industrial and medical use) and design technology must be powerfully and rapidly developed as systematic research. Currently, in technologies which are not R&D targets in the Industrial Science and Technology Frontier Program, through collaborative research between industry, the government, and academia with assistance from machinery promotion funds, the following exploratory research will be performed so that establishing micromachine technology systems is not hindered.

(1) Micro science and technology (tribology and mechanics)

(2) Materials technology (actuator materials for industrial and medical use and materials suited to living bodies in medical treatment)

(3) Design technology (design methodologies)

(4) Control technology (control methodologies)

(5) Energy transmission in micromachines

4. Activities of the Micromachine Center

The Micromachine Center is the center for managing the exploratory research described above. It promotes exchanges between domestic and foreign organizations by collecting and disseminating information, dispatching and receiving overseas missions, and sponsoring and participating in symposia, and promotion. Its activities are based on the five pillars given below.

In addition, a member support system will be established. This system is expected to cooperate in the daily operations of the center and participate in its use and planning its operation.

(1) Studies and research on micromachines

(2) Information collection and dissemination about micromachines

(3) Exchanging and cooperating with domestic and foreign organizations related to micromachines

(4) Promotion of standards for micromachines

(5) Teaching about micromachines

5. Prospects for micromachines

Micromachine technology is thought to have uses in a broad spectrum of fields. The following results are expected when looked at from the perspectives of industrial technology, the economy, and society.

Industrial technology: High-level functions are advancing rapidly due to the introduction of micromachine element technologies to existing industrial parts. For example, the miniaturization and unification of various sensors, actuators, and mechanisms can lead to higher precision optical disks and advanced, multifunctional industrial robots. Implementing the latter will change industrial production systems.

Economy: Since micromachine technology covers a technology range that cannot be addressed by existing technology, new technological fields (micromachine development, production, and use) will be created.

Society: An industrial society supported by vast technologies invites remarkable increases in energy consumption. Micromachine technology is tied to saving energy and resources through the miniaturization of machines and is a technology that places a small burden on the environment. Moreover, in an aging society, advances in medical technologies by micromachine technologies are essential.

IROFA Official on Status of and Prospects for MAP

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[Article by Masaichi Ikeda, section chief, MAP Investigation Group, International Robotics and Factory Automation Center (IROFA)]

[Text]

Introduction

Signs of recovery are not seen in corporate plant and equipment investments and the performance of a number of manufacturing industries is worsening. Moreover, with the rapid rise in the value of the yen since spring, ambivalent feelings about the future of the economy is increasing and work on curtailing costs of initial plans is expanding. In this kind of climate, it is becoming difficult to secure future investment and start up major systems like building computer-integrated manufacturing (CIM), a system for designing the optimization of manufacturing activities and sharing information among the sales, design, and manufacturing divisions where all of the activities related to manufacturing are connected by a computer network, that is just beginning to be aggressively tackled by manufacturing industries.

As a result, recently, the two obvious extreme specializations are corporations that are increasing productivity by restructuring their manufacturing lines and possible investment in plant and equipment as early as possible and corporations that assert that there is no alternative to advanced automation in order to construct variable type, variable quantity production and multiple products, small quantity production. That is, to skillfully handle the environmental changes that surround the following kind of CIM, manufacturing industries are searching for the measures that must be taken to ensure their survival.

(1) Substantially decrease manufacturing costs

(2) Address the trend of multiple product class products

(3) Reduce the lead time between product design and the manufacturing process

(4) Address the shortage of skilled workers

(5) Harmonize the manufacturing facilities and the workers

(6) Convert to resource and energy conserving manufacturing facilities

(7) Extend product liability to the product

In the computer network technology field, indisputable issues are appearing and a new era will be visited. The key words related to a series of distributed processes are network, downsizing, open system, multimedia, and client-server. In existing manufacturing systems, the distributed processing environment for downsizing is being implemented in connection with factory automation (FA) network technology from the quality and hierarchical nature (defined by the ISO/CIM reference model) possessed by these manufacturing systems. The cell (line) controller (FA computer) that controls the manufacturing equipment controls other manufacturing equipment (e.g., robots, numerically controlled (NC) tools, programmable logic controllers) and builds a manufacturing system environment not offered in a single cell (line) controller. In the production message specification that is a representative application protocol considered by the MAP (Manufacturing Automation Protocol) initiative, first, the architecture that supports this cooperative relationship is called the client-server model. The standardization of not only information exchange methods, but also the behavior description on the server side (introduction of the virtual machine concept called the virtual manufacturing device) had a significant effect on the methods for building later manufacturing systems. Figure 1 shows the structure of the client-server model.

The concept of this client-server model expresses the relationship between the server side, which offers services that cooperate on the network, and the client side, which receives the service. An important point is the server can simultaneously offer common services to multiple clients. If needed, the server role and the client role coexist in one node, for example, a cell controller, and can properly use these roles in response to the situation. When this is applied to manufacturing systems, the client is the application that controls the manufacturing equipment, such as the FA computer, cell (line) controller, or workstation. The server is the side that executes requests from the client and will be manufacturing equipment like robots, numerically controlled tools, programmable logic controllers. The merit of the client-server model is communication exchange that was simplified between several clients and the server that becomes the foundation is distributed and the whole system captures the model constructed from this mixture. The results of simplifying the whole system are a decrease in the development and operating costs of the whole system and an improvement in reliability.

In this paper, I would like to describe the current state of activities to disseminate MAP and the technologies surrounding MAP still under development and for future development.

Directions of the MAP Open Committee (Japan MAP Users Group)

Ten years have already passed since MAP was advocated by General Motors in the United States in the beginning of the 1980s.

The International Robotics and Factory Automation Center (IROFA) set up the MAP Committee in

November 1985 in response to global trends. Its activities centered on the two tasks of (1) domestic public relations on the importance of MAP and (2) contributions to extend MAP specifications.

IROFA received a commission from the Ministry of International Trade and Industry (MITI). Based on cooperation between industry, the government, and academia, R&D projects on the Factory Automation Interconnection System (FAIS) were implemented over a three-year period from 1987 to 1989. Along with establishing interconnection technology, arrangements were made to establish the MAP Test Center in the Technology Laboratory of the Japan Society for the Promotion of Machine Industry and basic preparations for standardization activities in Japan were performed.

With the objectives of effectively using the results of the FAIS project from 1990, disseminating the results in Japan and abroad, and contributing to the international standardization of communication protocols, the FAIS Network Event (FNE) project was started. In June 1992, a proof-of-concept demonstration simulating an actual plant was implemented as FNE'92 and proved its effectiveness.

In order to include FAIS 2.0 in the MAP/TOP 3.0 Specification: 1993 Release as the MiniMAP protocol, a working group was established and a protocol was created.

In this committee, taking the opportunity to establish the MiniMAP protocol, based on prior achievements of MAP and MiniMAP, the range of activities will be expanded in the following way.

(1) Expansion of the range of activities from MAP to FA network communication environment (Technology)

(2) Strategic software from standardization activities to dissemination activities (Planning)

(3) Expansion of the range of activities from communication protocols to application software (Technical results)

Consequently, starting this year, in addition to promoting information collection, surveys, public relations activities, and international standardization related to MAP, MAP will be positioned as the core technology of the FA network to address the demands of a new era. By focusing on preparing the FA network environment based on users' needs, active dissemination of MAP was planned.

Accompanying the expanding range of activities, the name of the committee was changed.

New activities

(1) Developing a MAP open system (simplification of connections to private networks)

(2) Establishing utilization technology that unified the MAP relation through cooperation with related industrial associations and ISO (development of utilization technology of MMS companion standards)

(3) Simplification of MAP utilization technology (gap solution of utilization technology between the application level and user program)

(4) Actively addressing the obstacles of introducing MAP

(5) Expanding the fields to use MAP

Name change of the MAP Committee

As explained above, the activities of this committee are connected to the task of expanding the range of activities from MAP to the network environment required in CIM. Thus, beginning this year, the name of this committee was changed to the MAP Open Committee.

Old name: MAP Committee

New name: MAP Open Committte

However, the Japan MAP Users Group (JMUG) has the same name as before for the MAP/TOP World Alliance.

Complete Revision of the MiniMAP Protocol

The 1993 edition of the MAP/TOP 3.0 Specification, which is the international standard communication protocol for factory LAN, was formally approved at a general meeting of the MAP/TOP Users Group World Alliance held in San Francisco. The FAIS 2.0 specification factory communication protocol developed in Japan is included as the MiniMAP protocol. The 1993 edition of the MAP/TOP 3.0 Specification is slated for publication in November.

In the move towards implementing CIM in manufacturing industries, the communication protocol of standardized LAN for FA factories is required to make possible the interconnection of different machines in a manufacturing plant.

Although there is MAP (alias Full MAP) as a communication protocol for factory LAN, the original MAP strengthened its position as a trunk line network. Therefore, the early implementation of MiniMAP was expected to be a communication protocol at the cell level which is suited to manufacturing facilities particularly in Japan.

Approval this time gave global recognition to the usefulness of the FAIS 2.0 Specification. The FAIS 2.0 Specification will be incorporated as an option of the MiniMAP protocol. As a result, MiniMAP is a communication system at the optimum cell level in the interconnection of FA equipment. In the future, the implementation of factory automation and global dissemination are expected with MiniMAP as the bearer promoting open manufacturing equipment, such as FA computers, controllers, and robots, and multivendor systems.

The features of the FAIS 2.0 Specification are

(1) the use of an auxiliary protocol,

(2) the addition of network management functions,

(3) use in manufacturing message specifications, and

(4) the development of subsets of manufacturing message specifications.

Trends in standardizing the manufacturing message specification (MMS)

The features of MAP 3.0 completely conform to OSI as the basic standard and stipulates the MMS equipment specifications (function standard) that became the international standard ISO/IEC9506-1 and -2. MMS was stipulated as the application level protocol (OSI level 7) as the service element to achieve remote control through an FA network of FA manufacturing devices like robots, numerically controlled tools, and programmable logic controllers. The service that MMS performs for applications on the client side is divided into 10 types of objects and 86 types of services. To be able to handle each FA manufacturing device on the server side from the client side, these features implement the manufacturing devices in the virtual machine model (VMD) and the instructions used by MMS for this VMD are sent from the application on the client side. In accordance with the received instructions, VMD reflects the request in the operation of actual FA manufacturing devices. This action is one function of VMD and is not an application instruction at the client.

The MMS standard is created from the core standard and the companion standard. The core standard stipulates the service definitions and protocol specifications of MMS. Detailed specifications which apply to actual manufacturing equipment are stipulated in the companion standard for each type of manufacturing equipment described in section 4.2.

In addition, plans are proceeding to use MMS technology as the tool to integrate real-time data exchanges between control centers in the electronics industry in the United States.

1. JIS standardization of MMS

When the source text is translated from the position of totally respecting the ISO/IEC standard created with the agreement of each nation, the Japanese Industrial Standard for the MMS core standard (ISO/IEC9506-1, 9506-2) will be standardized by JIS without changing the technical content or the standard format. Formal publication is expected from the Japanese Standards Association within a year.

2. Standardization of the MMS companion standard

International standardization activities of each companion standard are performed by the ISO/TC184 which is in charge of corresponding manufacturing equipment and a special committee of IEC/TC65. The robot companion standard (ISO/IEC9506-3) becomes ISO/TC184/SC2/WG6. The numerical control companion standard (ISO/IEC9506-4) becomes ISO/TC184/SC1/WG3. The PC (PLC) companion standard (CD9506-5) becomes IEC/TC65/SC65B/WG7. The process control companion standard (DIS9506-6) becomes IEC/TC65/SC65C/WG1.

In Japan, a domestic committee will be established in the special committee of ISO/TC184 and IEC/TC65 and will actively participate in the creation of international standards. The Japan Industrial Robot Association is in charge of the robot companion standard. The Japan Machine Tools Association is in charge of the numerical control companion standard. The Japan Electronic Instrument Industrial Association is in charge of the PC (PLC) companion standard and the process control companion standard.

3. Progress of the MMS International Standardized Profile (ISP)

MMS was developed as one application level of the open system interconnection (OSI). In ISO, development was not an OSI promoted source (ISO/IEC JTC1) of TC184 (industrial automation) and is still not formally recognized in the OSI world. In TC184/SC5 which is the development body of MMS, activities have begun for formal recognition of JTC1 as one service element of OSI. To do this, the required technical document is called the International Standardized Profile (ISP).

In a word, ISP is a common global implementation specification. The different implementation specifications determined based on ISP and several groups advocated by OSI will be unified; this will be desirable in MAP.

ISP was assigned to and created by work groups in three regions with mutual approval and was uniformly shared worldwide. Agreement by the three regions is necessary to achieve ISP and this agreement is unique. This cooperative work is called harmonization. The three regional workshops are the OSE Implementors' Workshop (OIW) in North America, the European Workshop on Open System (EWO) in Europe, and the Asia Oceania Workshop (AOW) in Asia and Oceania. Their secretariats are the National Institute of Standards and Technology (NIST) in the United States, AFNOR in France, and INTAP in Japan. Specialists in each protocol of each level are gathered and special interest groups (SIG) are being formed in each work group. Already existing SIGs related to MMS are MMS-SIG and EG-MMS in OIW and EWOs, respectively, and they have promoted ISP activities, but there is no MMS group in AOW which was a problem. Since this was based on a special situation in Japan, OSI standards, implementation specification (function standard) review, and international studies were performed by INTAP, however, only MMS was under the responsibility of IROFA. But it was decided to establish the MMS-SIG in AOW at the AOW general meeting in April 1992. That secretariat and operations base in Japan were placed in IROFA.

Currently, MMS's ISP is close to completing the profile denoted by AMM11. AMM11 is the MMS general use, basic profile. MMS service is a minimum set that only includes the status outside of essential services in the standard.

In addition, new actions that should be noted are the decisions on the ISP implementation specification of the MMS companion standard, on the responsible regions, and on the work schedules. Work began by undertaking the compilation of the robot companion in AOW and the numerical control companion in EWOs.

Preparation of the MAP Product Database

In IROFA, one link in the dissemination of MAP products was building a database related to the circumstances for producing MAP/MiniMAP (FAIS) products, and planning and beginning a system service that can be freely searched for data the user wants to know. Currently, the database has recorded about 106 systems of MAP products at 19 major domestic companies. Of these, 39 systems passed the MAP compatibility test.

The *MAP Product List* that lists the collected data was created at that time. MAP products (full MAP and MiniMAP) are classified into the five categories of (1) interface boards, (2) independent devices with interfaces, (3) application software and basic software, (4) transmission equipment and other equipment, and (5) relay equipment and MAP/EPA. (See Table 1 for details.) Of course, the product specifications in the registered information include items that users would like to know like product type, sales status, product functions and features, price, delivery, and contact for inquiries. This MAP product database is useful in gaining an understanding of the current state of MAP products and decision material for model selection.

Future MAP Development

The MAP/TOP World Alliance accomplished its main mission of the 1993 edition of the MAP/TOP 3.0 Specification. In the future, the era of searching for the form and role of the new MAP will be encountered.

The dissemination of MAP has never attained initial expectations, but the private users' group, an organization that continues activities on a global level on advanced proposals, demonstration test facilities, and compatibility tests on many standardization activities for over 10 years, is a magnificent model of international cooperation.

As for the networks needed in CIM in Japan, a variety of private networks (proprietary corporate networks) exist in field networks situated in the lower level of MAP. Their existence is not ignored.

Therefore, the Japan MAP Open Committee developed the common technical specifications for open systems capable of interconnecting various private networks that are developed in this lower level of Full MAP and MiniMAP proposed earlier. Next, with support of MITI, research was carried out on demonstration tests that used a gateway (prototype) implemented by this common technical specification.

On the other hand, the MAP/TOP Global Alliance examined long-term issues at this year's meeting and regional representatives were sent for each of the following themes. Each regional representative expressed interest on various themes, but only a few were settled. Issues of concern to each region were individually tackled.

(1) Manufacturing/industrial focus

(2) MAP in the context of other factory communication's technologies

(3) Small and medium size company use of MAP

(4) Enabler and application software for MMS utilization

(5) Focus on MAP promotion to encourage its use

(6) Link to other OSE components

(7) Maintain and enhance MAP 3.0 Specification (including more to smaller documents)

(8) Connect with IMS projects

In the future, Japan will work with the American and European MAP users' groups and international contributions are expected in this field of activity. However, more effort is needed from the participants.

Table 1. Registered Classes of the MAP Product Database

Class	Product Class	Pertinent Class
A	MAP interface board	MAP interface board
B	Independent equipment with MAP interface	Mainframe computers, minicomputers, workstations, personal computers, PLCs, robots, NCs, MAP adapters, network test equipment, etc.
C	Application software packages, basic software	Application package based on API (or suitable product), product with suitable protocol stack under API (or suitable product)
D	Transmission equipment, etc.	Head end remodulator, trunk amp, head end auxiliary equipment, modem, coaxial cable, taps, connectors, etc.
E	Relay equipment and MAP/EPA	Gateway, MAP/EPA, routers, bridges, repeaters, etc.

MITI/AIST Official on Industrial Machinery Technology R&D

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[Article by Toshio Ojima, Planning Group, Mechanical Engineering Laboratory (MEL), Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI)]

[Text]

Introduction

As a national laboratory, the Mechanical Engineering Laboratory (MEL) is responsible for creating new technologies in research fields in a wide range of basic research on machinery technology. One central research field is research on industrial machinery. In this paper, I focus on research derived from industrial machinery and present research on machinery elements in manufacturing systems. Within this limited lineup, principal basic research involves issues in various research strategies from small-scale element research to large-scale R&D projects in progress with the cooperation of outside research institutes, for instance, in related industries. (The old Large-Scale Project and Next Generation Industrial Basic Technology Development System have been unified since 1993.) First, I will present an overview of related research being carried out at MEL, then describe ideas on future research directions.

Research Overview

Table 1 shows research themes closely connected to industrial machinery focusing on manufacturing system and machine tools in MEL. In Table 1, this research is classified as research on machinery and machine elements, research on measurement and control, and research on manufacturing systems. A brief description, and the starting and ending years for each research theme are listed. It shows the technical content of each research theme and what is the established goal for the beginning and the end. A large part of the current research themes reflects past research developments. Therefore, explaining the research situation at only one time is unsatisfactory. However, I believe this is one arrangement to enable understanding of the current situation. Numbers enclosed in brackets in this paper correspond to numbers in Table 1.

Table 1 Research Themes at MEL (1993)

Number	Research Topic	Period	Description
	Machine Elements		
1	Research on the transmission characteristics of machine elements	1991-1993	Empirical analysis of gear's vibration, noise, torque, and torsion characteristics
2	Research on damage to the rolling surface	1993-1996	Explanation of rolling fatigue of steel surfaces
3	Basic research on tribological control of machine elements by electromagnetic fluid	1993	Explanation of the phenomena between surfaces in contact where a concentrated load and a shearing force act simultaneously
4	Character recession of machine tool parts joining parts	1992-1994	Evaluation methods of sleeve, thermal transmission, and friction characteristics
5	Development of block forging technology, silencing technology for forging machines	1993-1995	Empirical explanation of the deformation characteristics of forging, measuring the sound surface vibration characteristics and transmission route
6	Foundation of comfortable machines	1991-1993	Proposal of new machine concepts based on the biological rhythms of person operating the equipment
	Measurement and Control		
7	Research on measurement technology of large diameter plane mirrors by hologram elements	1993-1995	Planar measurement method using hologram elements that use a liquid surface as the reference
8	Research on new optical function element technology using information processing	1989-1993	Development of noncontact and real-time measurement methods of the rotational speed and the center of rotation
9	Research on wavelength sweeping interferometer technology	1993-1994	Measuring the shape of large uneven objects and objects with level differences by interference applying wavelength sweeping
10	Research on hologram interferometers using high precision shape measurements	1991-1994	Research on high precision shape measurement methods for mirror surfaces
11	Control technology for mechanical structures	1992-1994	Generation and control methods of unified operation stressing units of multiple devices

Table 1 Research Themes at MEL (1993) (Continued)

Number	Research Topic	Period	Description
12	Research on intelligent control process technology	1989-1993	Real-time intelligent process control methods and processing diagnosis
13	Research on magnetic levitating, absolutely stationary stage systems	1991-1995	Development of absolutely stationary stage by 4-point supports and control methods for minute vibrations
14	Research on virtual space machine technology	1991-1995	Heat compensation for machine tools and workpieces using neural networks
15	Ultraprecise machining process technology (advanced processing system)	1992-1994	Methods to improve the heat characteristics of air control pressure axis and process system compensation
	Manufacturing system		
16	Research in advanced human interface technology in machine tools	1992-1994	Interface functions rich with recognition abilities having multimedia functions
17	Basic research on knowledge representation methods for processing and search and inference methods	1993-1995	Expert systems for machining using a process database
18	Conceptual design system with advice functions	1992-1994	Create system development tool for design guides
19	Research on next-generation manufacturing element technology	1991-1993	Intelligent database for processing support
20	Research on manufacturing system integration	1991-1993	Display of the conditions of manufacturing system description methods and construction methods
21	Research on advanced compound welding systems for different materials	1991-1993	Development of welding systems for different materials of heat resistant and anticorrosive alloys
22	Research agent construction in new software structured model machine design	1991-1997	Research on object oriented languages for design and planning algorithms based on the agent concept
23	Ecofactory technology	1993-1994	Leading research on decreasing waste and recycling in the product life cycle
24	Research on appropriate methods to use a logic programming environment for creating intelligent processing systems in machine design and manufacture	1988-1993	Research on condition oriented, design languages
25	Research on formally creating CAD/CAM data exchange processing systems	1990-1993	Creating a CAD data exchange processing system
26	Research on technology to build next-generation manufacturing systems	1991-1993	Autonomous distribution of system elements and their integration technologies
	Processing technology		
27	Control by laser discharged in processing liquid	1992-1994	New processing technology dielectric using electric-discharge dielectric properties from lasers
28	Quality improvement of stamped products	1992-1994	Factor analysis of errors in micro stamping processing
29	Basic research on fine grinding mechanism of hard, brittle materials	1991-1993	Malleable mode grinding of ceramics
30	Research on high quality grinding of new com-. pound materials	1992-1994	Creep feed grinding of FRC
31	Thermal chemical machining of non-dielectric ceramics	1991-1993	Combination of machine processing of axial symmetric shapes and discharging in electrolyte
32	Improving welding and reforming techniques	1992-1994	Development of thermal CVD, hybrid CVD, and electron beam alloy methods
33	Research on improving ultraprecise grinding and find processing methods	1992-1994	Evaluating oxygen-free copper, small convex mirror surfaces and new processing technology

Table 1 Research Themes at MEL (1993) (Continued)

Number	Research Topic	Period	Description
34	Research to improve ultraprecise grinding and fine processing methods	1987-1993	Development of plasticity process simulator
35	Research on beam-aided hybrid processing technologies	1987-1993	Film formation by laser plasma-enhanced hybrid CVD methods
	Leading edge processing systems		
36	Research on original technology for wide area, ultraprecise surface shapes	1993-1996	Long wavelength domain grinding and magnetic lithography in the short wavelength domain
37	Research on processing highly regular lattice material	1992-1996	High precision and highly efficient processing technology through the cooperation of molding, joining, and machining processes
38	Research on manufacturing technology for highly functional, metal thin plates	1991-1995	Direct manufacturing technology for highly malleable thin places having uniformly fine crystals
39	Advanced laser processing systems	1993-1997	Surface reforming and shape measuring by advanced application of lasers
40	Research on surface processing and quality improvement technology	1992-1995	Development, control, and evaluation of wear-resistant surface reforming methods
41	Compound micro processing technology (micromachine technology)	1991-	Fine grinding processing, ion injection, micro joining

The content and position of each research is outlined for the class of technical elements in manufacturing machinery technology. Of these, the themes from ecofactory technology and the IMS Project addressed in this paper are briefly described [23], [19], [20], [26].

1. Machine elements

The research themes shown in Table 1 supplement the themes for clarifying phenomena.

In research on the transmission characteristics of machine elements, tests are performed on power losses of high tooth adjusting gears. The main factors demonstrated were windage loss and agitation loss. Windage loss is proportional to the speed from the power 2.3, and agitation loss clearly exhibits exhaust in the axial direction of lubricating oil of the claw part. The aim is to establish new design methodologies to revise established theory [1] by systematically advancing these tests. Similarly, in research on bearings, there are research on the rolling fatigue of bearings, research emphasizing the explanation of proposals and phenomena of new models represented in abnormality diagnosis technology using acoustic emissions (AE), and research emphasizing the development of new elements for added value, making prototypes of ceramic bearings and analyzing their behaviors, and determining the suitability of silicon nitride as the material for rolling bearings [2], [3]. Research is also proceeding on collecting basic data and evaluation methods to evaluate wear when ceramics are used on the sleeve surface [4].

There is both the accumulation of long-term experimental research and research that advances basic elemental technologies one step at a time [1]-[5].

In research on comfortable machines, the proposal assumes "when machines are driven by the biological rhythms of the people operating them, the feeling of a united body of the operator and the machine is born and the operator feels comfortable." In the desire to apply this to machine tools, experimental research using heartbeat signals is underway [6].

Research on structural materials continued in the 1980s research on ceramics, FRP, and adhesive structures used in machine tool structures like the base. Measurement data related to changes over the years are being accumulated on the adhesive structure milling machines developed using the elements of steel plates and steel tubing joined by epoxy adhesives.

2. Measurement and control

Control that uses the machine's behavior, measurements of process phenomena, and their data are widely studied from the two perspectives of theory and practice.

In research on an absolutely stationary stage based on magnetic levitation, in order to isolate vibrations transmitted from below the stage, such as a floor, the feeling of a solid body consisting of the stage and the floor are removed. The absolute system that is the reference is not determined externally but is the absolute speed. In order to improve the resolution of speed measurements, a major feature of this research is to determine a reference in absolute acceleration. Previously, tests on vibration isolation in the forward direction of a ship where four magnetically levitated machines were located on an aluminum honeycomb structure foundation (50 kg) have been successful and vibrations from 2 to 800 Hz were suppressed. In the future, studies will be added on suppressing air swaying caused by noise and controlling vibrations in three directions. These kinds of control methods are expected to be future successes as fundamental technologies which are to be widely used in ultraprecise machine environments [13].

Although proposals are appearing for various methods of optical shape measurement technology research, the current central theme is based on interferometer methods using lasers [7]-[10], [15]. For example, control systems are being developed based on noncontact measuring of the relative positional relationships of the processed surface and tool position. At a resolution of 10 nm, measurements across a 80 mm stroke become possible. In addition to future studies on various methodologies, research is expected to continue on on-machine and in-process measurement technologies.

In addition, research is proceeding on ultraprecise position setting using piezoelectric elements.

Research continues on obtaining higher precision and advanced functions centered on machine tools from different angles in algorithmic control. In research on intelligent control processes, tests are continuing on detecting process resistance by distortion sensors integrated with the rolling bearings. Then, tests are performed for abnormality diagnosis of the process by processing this signal. This diagnosis is performed by knowledge processing control equipment based on an inference mechanism using expert knowledge. The feature of this control equipment is preserving the real-time nature from the perspective of controlling machine tools. That is, "required control operation is completed to avoid an abnormality before a fatal breakdown of the process system by an abnormal condition or deterioration of the tolerated process precision." Therefore, control equipment is event-driven and has a hierarchical structure. In the end mill process that uses computerized numerically controlled (CNC) machine tools, it has been verified that after information generated by chatter vibrations is received, control can be completed in 0.8 seconds until its disappearance [12].

The temperature of each part in a machine tool is measured and the heat deformation of machine tools is estimated using neural networks. Prototypes of control systems that compensate for changes due to heat deformation are being created and studied. This research is used where air conditioning constitutes over 60 percent of the energy used in a factory with high precision machine tools. This research is founded on the recognition that high precision processing in a normal environment is indispensable in order to reduce energy consumption in the factory. In other words, this proposes ways to use machine tools that are kind to the earth. In experiments using milling machines, the possibility of learning control that positions within a minimum precision of 5 μm in a temperature difference of 5° is indicated [14].

3. Manufacturing systems

The research subject is a system of an assembly of machines. By including current successes of information processing technology in machine technology, manufacturing machines which were previously unavailable will be created. In addition, new functions can be provided in manufacturing machines acting as a system. These are represented, for instance, by NC machine tools and robots. A manufacturing system is a system concept that focuses on machine tools in which manufacturing tools have a central existence.

Research on next-generation manufacturing systems is being advanced through international collaborative R&D on technological developments that provide high level integration, modularity, and independence in open architecture [20]. In research in this field, the technology of software systems plays a major role [16]-[18], [21], [24], [26].

As for design systems, by developing an object-oriented function design language (FDL) containing conditions and database functions and tests that exercise the spindle design of a lathe, it will definitely be effective as a general-purpose tool for routine design tasks. Also, cooperative planning algorithms based on the agent model are being developed and applied to machine assembly and disassembly to allow flexibility in unforeseen situations.

Research is underway on the development of international standards related to the representation format of the product data model. A prototype CAD data exchange system is created, and testing and evaluation methods on the compatibility of data based on the exchange tests are determined [25]. In the automation of design and manufacturing processes, determining the standard form of the model's representation of target products achieves technological leadership as well as provides a research base and encourages further development.

Standardization research is continuing centered in the factory automation (FA) field, but it is very important to advance standards developed simultaneously with R&D. As a national laboratory, MEL is promoting the expansion of research preceded by standardization and contributing to the creation of international standards from the position of international research collaboration.

In addition, technology to build future machine systems and research on distributed machine group control methods are examined from the perspective of flexibility and extendability.

4. Processing

A major research subject at MEL in manufacturing machinery is process technology.

Process technology is a utilization technology for process machines and tools for creating the desired shapes without damaging the properties of the target process materials. Moreover, this technology provides stable desired features in the materials like welding and surface reforming. Research on processes includes research to determine the optimum process conditions in the given materials and research on the deterioration of tools occurring over a long period of time. Data is being accumulated [28].

To advance more precise processes, research is emerging to clarify the process's phenomena at the material's atomic and molecular levels, new processing methods, and the fusion and combination of each process [27], [29]-[31], [33], [36]-[38], [41].

The research includes improving the surface from the perspective of tribology. Starting with lasers, process techniques using beams differ from previous machine processes. As a result, practical use by combining with existing technologies is beginning [32], [35], [39], [40].

Research is underway on processes for hard to grind materials that do not damage the material's characteristics and process under optimum conditions in principle when new materials emerge. Also, a database is used and research proceeds on the process conditions for unknown materials [17], [21].

In the development of new materials, its molding (process) technology development must accompany it. The research directions in machine technology must develop both new machines and new materials and advance based on their cooperation.

Future research to compute and clarify the phenomena using computer simulations is critical in this field [34].

Future Trends in Research on Manufacturing Machinery Technology

1. Research directions at MEL

Machine technology stipulates the forms of functions that should be carried out by the machine and implements them through the transmission of power and motion. Current machine technology is based on mechanics and is developing by actively introducing information science, materials science, and mathematics. Machinery technology is the basic technology that supports all manufacturing. When each one is looked at, the two bases of basic research and applied research are developed through adept mutual development.

As a national laboratory, we must have a clear position on how research should proceed. It is crucial to have the two perspectives of original research to produce technologies that give rise to new industries and research on important technologies for products of advanced technology and to establish mechanical systems that support social systems. At MEL, the research objective is to create advanced mechanical technology in harmony with people and the environment. As shown in Figure 1, the major objectives of the research are to understand autonomy, microminiaturization, and concurrency. These directions have been explained in this paper and are identical to research on industrial machines centered in industrial systems.

Autonomy means the target machine system independently performs its tasks, without receiving assisting instructions, by making decisions based on a model of itself and of its environment. This means the system has the ability to perform in harmony with other machines, or people depending on the situation, and has a high level of independence. This concept includes implementing intelligence, automation, and advanced functionality. To address the aging of skilled workers and the dearth of young workers, high functionality of machines is also being promoted while planning for the harmonization of man and machine.

The research direction on autonomy is closely related to manufacturing systems. To advance mutual cooperation between the movement of objects and the transmission of information between machines in a distributed structure, the group of machines in a system is recognized as a manufacturing system. The number of machines, which is a critical element in mutual cooperation, ranges from 10 to 100 and is moving towards 1,000. In these kinds of systems, management which is premised on the autonomous nature of each machine becomes essential. In addition, research observing the key words of autonomous, distributed, and integrated is important from the perspective of maintaining redundancy and flexibility. Autonomy can pursue the criterion found in living organisms.

Microminiaturization designs for the miniaturization of machines by targeting structures of mechanical systems that have advanced functions, and planning for the realization of superior medical care for people, or facilitating the maintenance of complex machines and systems. The course is moving towards establishing better defined bounds of mechanical technology. Research on microminiaturization is not only the microminiaturization of machines, but involves a range of material technologies and energy technologies.

Greater precision related to manufacturing machines can be described as microminiaturization. The processing precision of machine tools is moving from one millimeter of the Industrial Revolution, to one micrometer, then to the order of nanometers. Within this trend, the measurement light source changed from visible light to ultraviolet light, then to X-rays. Shorter wavelengths in the energy beam for light sources used in fine processing are also rapidly developing.

Concurrency designs for breakthroughs by integrating technologies or systems built in a distributed or sequential form into the concept of concurrency (simultaneously parallel). It has a far-reaching meaning that includes concurrent engineering in manufacturing. In the manufacturing field, not only manufacturing systems composed of design and manufacturing technologies, but restoration systems composed of disassembly and material recycling technologies must be considered. Moreover, even in the energy problem, a concurrent viewpoint is required to gain comprehensive understanding

in order to harmonize the environment with the generation of carbon dioxide caused by using fossil fuels for energy.

There are rapid developments in the computer industry and accurate simulation using computer models is a critical technology in developing concurrency. To advance this research, a wide range of theoretical and experimental research is necessary.

2. Future research themes and their contents

Illustrated below are research themes that must be developed in the future and are directly related to manufacturing machinery technology.

- Use and processing technology of diamond thin film

The use of diamond thin film is expected to be developed for sensors and semiconductor materials, in addition to developing areas that use them for their hardness. Technologies for manufacturing and processing the material properties and shapes to match the objective for using diamond thin films must form the new industrial base for the future. This research is typified by research in microminiaturization.

- Strain free processing technology

Corresponding to their use objective, new materials created by controlling structures at the molecular and atomic level as in C_{60} and carbon nanotubes demand the use of new processing technologies like advanced laser processing, STM processing, and annealing technology operated at the microscopic level that will not destroy the material's structure. Heat problems which arise during micro processing must be conquered. This research is related to microminiaturization.

- Mechanical technology using the skills of expert technologists

Research is essential on the systematization and analysis of machine functions and action controls in order to reproduce the skills, explanations of the uses of senses, actions and extent of human strength, manufacturing process systems that understand common sense as technologies to reproduce and apply in practice based on systems that use robot engineering and possess the high-level technical skills held by expert technologists. In addition, in the manufacturing environment, the research targets are machines that have human interfaces which stress suitable operability and humanity, and technologies where the creativity exhibited only by people is guided and manufacturing activities are performed. This research is moving in the direction of concurrency and autonomy. R&D related to the research content of human media and master machine technology (tentative name) and preparations are proceeding for advanced research that must begin in the Industrial Technology Group in 1994.

The above research is flanked by technologies to advance new industries. Research is important from the perspective of implementing these kinds of technologies in the areas of daily life or preparation as technical infrastructure in industry. Research on the standardization of advanced technology is representative of this.

Conclusion

Research at MEL centers on basic and fundamental research. Basic research has the objective of bringing about the creation of new technologies and is connected to a wide range of fields. This means the results of the themes presented here will have a major impact on technologies related to manufacturing machinery in the future. For example, research on welfare devices are not directly related to industrial machinery technology, but this technology must consider the perspective of man-machine interfaces with the participation of senior citizens and the disabled in society and the perspective of the necessity of building a new manufacturing system's structure for machine production that corresponded to a variety of circumstances of each user.

In this paper, I presented an overview of research underway in the Mechanical Engineering Laboratory and described directions for the near future. At MEL, research is performed on (1) robot engineering, (2) energy engineering, and (3) biomechanical engineering for manufacturing machinery, and (4) on measuring and controlling materials. These research areas are developing in close mutual association. The results are both directly and indirectly related to manufacturing machinery. Micromachine technology is one notable technology with hidden possibilities.

Research results of the Mechanical Engineering Laboratory are primarily expressed in the form of technical contributions beginning with conference papers in special fields. Also, research topics are adopted at the monthly meeting of the Mechanical Engineering Laboratory and the monthly *MEL News*.

MITI/AIST Official on Ecofactory Research

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[Article by Tatsuya Fushiwara, Industrial Science Technology R&D Group, General Affairs Department, Agency of Industrial Science and Technology (AIST), Ministry of International Trade and Industry (MITI)]

[Text]

Pioneering Research

Since 1993, the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI) has integrated the National Research and Development Program (Large-Scale Project), the Research and Development Program on Basic Technologies for Future Industries (Next Generation Project), and the National Research and Development Program for Medical and Welfare Apparatus (Medical and Welfare Equipment Technology Program) under the newly

initiated Industrial Science and Technology Frontier Program. The Industrial Science and Technology Frontier Program addresses both (1) fundamental original research and development aimed at building new technology systems and achieving rapid breakthroughs in technology and (2) public, social, and welfare research and development on important issues from the perspective of the public welfare, and resource problems which are difficult to address independently and constructively by the private sector. This program is built by examining leading research to perform preliminary, basic studies and research including studies on the pros and cons of developing projects on themes which are difficult to immediately develop into projects.

Ecofactory technology is one pioneering research theme which began in 1993.

Pioneering Research Background To Implement Ecofactory Technology

In Japan, which is faced with problems like space for waste disposal, there is a great deal of concern about existing problems of waste treatment and resource recycling. Related research is now being performed in each field. For example, in MITI's Large-Scale Project, R&D has been performed for 10 years from 1973 to 1982 (total budget ¥12.6 billion) with the objective of harmonization of effective resource utilization and municipal waste processing; acceptable results were obtained.

Almost all of the research on waste focuses on the problem of how to efficiently process current waste and is completely independent of the manufacturing field. Realistically, technology development concentrated on burning or burying waste. Research on recycling resources involved no more than a portion of recycling techniques where quality drops.

However, the inability to apply conventional recycling processing due to the appearance of new materials to the substantive problems of the wastes initially conceived was added to Japan's waste disposal problem. There is an increasing seriousness in processing problems.

However, mechanical technology is anticipated as an effective technology to solve these problems. Mechanical technology is broadly classified into manufacturing technology, organization and design technology, materials technology, robot and intelligent technology, and energy technology. Later, major developments came with the fusion of information systems and bioengineering. In the future, to respond to societal needs and to search for new needs, the major directions of the harmonization of the machines environment, micro systems, and autonomy are being formed and developed.

Environment harmonization considers applying machine technology to conquer major problems in current social systems like decreasing pollution sources, repairing the environment, and effective use of resource energy. Within the various limits in the social system, new environmental harmonization factors will be introduced and implemented in manufacturing systems.

Microminiaturization will be a complete paradigm shift of machine technology based on the principle of moving machines towards miniaturization, high precision, and function integration. That is, technology research will involve determining how to construct micromachines and effectively include phenomena characteristic of the micro domain not handled by previous machine technology systems.

Autonomy will allow us to pursue new machine control technologies to equip machines with more advanced automation, higher level functions, and harmonization of humans and machines.

Until now, industrial products were manufactured by manufacturing systems based on ideas from the manufacturer's position on how to decrease costs and high quality manufactured products. However, almost all product processing which was used was left as the responsibility of the government of each region. These dismantling systems were completely independent of the manufacturing systems adopted by the manufacturers.

Therefore, systems limited only to manufacturing attained highly advanced levels. But when the severity of postprocessing problems of actual engineering products is examined, the product life cycle is adopted as the total system. By introducing the concept of building superior products, the concept of the ecofactory was born because of product manufacturing and processing problems after use is troublesome from the perspective of social systems.

The Concept of the Ecofactory: Ecology Conscious Factory

The life cycle of industrial products, the primary targets in ecofactory technology, can be roughly classified into the manufacturing system of (1) design and (2) manufacturing, and the reduction system of (3) disassembly and (4) recycling.

An ecofactory is thought of as the whole system of the complete product life cycle process from (1) design to (4) recycling. The whole system is technologies seeking the optimum values related to the primary factors of the product's manufacturability, economy, marketability, performance, and reusability.

In other words, the fundamental idea behind the ecofactory is to introduce the idea of reusability in addition to manufacturability, economy, marketability, and performance which are the basic evaluation factors in manufacturing conventional industrial products.

However, reusability conflicts with the product manufacturing norm which to date has pursued only the manufacturing system. There is a great danger of the products themselves not having any market value. Namely, the introduction of reusability to extend current

manufacturing technology becomes a definite drawback in terms of evaluating conventional product manufacturing and marketing the product becomes difficult.

As a result, design technology that considers reusability beforehand must be established. Further, even in the manufacturing field, disassembly field, and recycling field, technology that considers reusability is introduced. Based on technological innovations in all of these fields, the optimum technology (the ecofactory technology) for mutual cooperation must be developed.

In this way, ecofactory technology is independent of conventional ideas about manufacturing technology and recycling technology. It is premised on (1) maintaining economic standards as product costs increase substantially and (2) not inviting a drop in product performance standards like product safety and efficiency. Ecofactory technology defines product manufacturing and reduction technology in which lower material quality does not result so the materials are used again after recycling in the same place in the same product.

The Relationship Between Ecofactory Technology and Energy and Resource Conservation

When looked at from the perspective of natural resources and energy, ecofactory technology keeps the introduction of new technology to a minimum when possible and reduces waste.

When only manufacturability, economy, marketability, and performance in manufacturing systems are stressed, inexpensive high quality materials are sought and often imported. Processing after these materials are made into products sends partial products overseas, but the vast majority are burned or buried after the useful portion of materials was extracted in disassembly and separation by hand or by conventional separation techniques. No plans existed to improve efficiency and manufacturability, thus, the amount of waste increased in proportion to product quality. By introducing ecofactory technology products, the rate of return from the reduction system to the manufacturing system will be increased resulting in major savings of resources and energy.

The Relationship Between Conventional Recycling Technology and Ecofactory Technology

Recycling technology is analogous to ecofactory technology. Recycling technology is reduction system technology to break, separate, and reprocess manufactured product waste.

The recycling concept can be broadly classified into the following four categories:

(1) Energy recycling where raw materials are burned and recycled as heat energy

(2) Cascade recycling that recovers and collects materials for the same system, however, the quality of the materials decreases

(3) Recycling mix where reuse is possible and a large quantity of new materials are added in order to prevent a major decrease in the quality of the materials

(4) Single recycling where material is circulated through only one cycle

When compared to ecofactory technology, this corresponds to

(1) Material cycles where resources in the form of materials and parts are usually circulated

(2) Horizontal recycling where materials do not have lower quality after recycling

(3) Full cycle where reuse is possible only after recycling

(4) Multi cycle that does not stop at only one cycle but focuses on multiple cycles

As a result, materials were burned as heat energy in the past. In collecting materials and parts and recycling materials, the objective is a technique that does not lower quality no matter how many times the material is reused.

The Promotion and Research System for Pioneering Research on Ecofactory Technology

1. Promotion methods

Definite future promotions will conduct studies centered on the following issues.

(1) Deriving the relationships between social system problems and ecofactory technology

In research on ecofactory technology, future ecofactory technology must be examined for actual inclusion into social systems. Therefore, not only research on ecofactory technology, but the problems of the ecofactory technology and the social system, such as how to collect and transport products or what the relationship should be with conventional recycling technology for product cleaning and pulverization, are all clarified. Then, assumptions are made about the social system and given this premise, discussions will intensify.

(2) Determining target products

To examine the possibility of constructing a system that embodies the ecofactory concept in addition to clarifying the relationship with social systems, the prerequisites become analyzing each technology such as manufacturing and disassembly. In order to compile the discussions, one or two target manufactured products are selected and the studies are limited to them.

The point that must be considered for the selection standard is the degree of compatibility to the scale of production. There are many perspectives such as, is recycling possible from a futuristic and technical perspective, or will recycling continue to be demanded by society. Products designated in recycling laws will be targets.

When we consider extending future research content into the finer points of each technology, whether the product or product parts regulations are appropriate must be determined. Depending on the situation, studies must proceed on each part.

(3) Establishing a time frame for using technology in society

Discussion is continuing on the target completion date for ecofactories. Developing the project is assumed as the first target, then element technology will be established within the next 10 years. Plans to implement it over the following 10 years are thought to be appropriate.

In this case, establishing a cycle to demonstrate the ecofactory concept is ideal, but in relation to the possibility of achieving the goal within this time frame, sufficient re-examination is carried out. When developing and implementing an ideal cycle is judged to be impossible during the assumed time frame, the necessary conditions for the standards, that is, maintaining quality and the material cycle, are given priority. In addition, what conditions exceed the minimum should be determined.

(4) Defining the idea of ecofactory products and examining the possibility of cycle completion for every product

The structural materials, assembly methods, and special functions for the products imagined to realize the ecofactory concept for every product determined in (2) will be defined and concepts about products that satisfy the ecofactory standard are clarified. Further, when the ecofactory is developed into a system from design to reproduction, the system that integrates technologies of whatever form must be studied. In this phase, a detailed examination of the techniques of every path for design and manufacture are deferred until later. However, while continuing to thoroughly understand the technology, a system structure will be implemented.

(5) Understanding the technology trends of every process and extracting technical development issues

Technology trends in every process that comprise the assumed system are determined. In addition to deriving technical development issues needed to realize the future target system, mutual technical relationships are also studied and technical issues during system construction are defined.

(6) Basic research review (cooperation with national laboratories)

The Mechanical Engineering Laboratory, the National Institute for Resources and Environment, and the National Institute of Bioscience and Human Technology are involved in basic research on new technologies for each process in the ecofactory. This research defines what contributions will be made to the ecofactory concept being examined in committee, propose needed basic research based on the circumstances, and promote research for fiscal year 1994.

(7) Studying the possibility of developing projects

After the technical issues of each process to establish the ecofactory and to develop the system are clarified, studies will begin on developing these research problems into projects in the Industrial Science and Technology Frontier Program.

The necessary studies center on whether this issue can be built into a new technical concept completely different from a conventional technology system.

In this phase, one method is to propose concepts that are completely different from conventional ecofactory technology.

Furthermore, in the review process, when other ideas appeared to contribute to the drastic promotion of recycling, modifying ideas in the review process was needed in addition to aggressively tackling these new ideas, so plans will be flexible.

2. Research system

As shown below [photo not reproduced], the R&D system sets up a planning committee in the Engineering Advancement Association of Japan which is consigned NEDO research. Here research is collected and placed in the technical subcommittee for each technology in response to need. Also, a working committee in charge of committee business matters is established in the planning committee.

The Mechanical Engineering Laboratory, the National Institute for Resources and Environment, and the National Institute of Bioscience and Human Technology are undertaking basic research on each ecofactory technology.

1993 Research at National Laboratories

The following research is targeted by the national laboratories for 1993.

(1) Design field (product technology)

Reusability is introduced into the evaluation standard. The design technologies and their supporting technologies, in order to realize a product life cycle that includes tradeoffs to avoid lowering manufacturability, economy, marketability, and performance, are

- product cycle model construction technologies and database construction technologies needed to optimize them, and
- design information system technologies to concurrently solve the tradeoff problems.

(2) Manufacturing process (manufacturing technology)

The objective of national laboratories is not pioneering research.

(3) Disassembly process (disassembly technology)

Technology able to automatically disassemble a variety of target products consists of

- powerful and small-sized autonomous robot technology with multiple degrees of freedom to rapidly disassemble recognized target disassembly parts into individual parts and materials.

(4) Recycling process (recycling technology)

The technologies to achieve the development of materials with excellent cycle properties and high quality cycles for materials are

- technology to recycle high quality products of low cost metal materials like aluminum alloys, and
- technology to automatically recognize and separate various mixtures of materials collected from discarded products, and measurement and control technology.

(5) System development technology

Technology to design and evaluate the total system where various technologies are efficiently combined, the performance of each product and quality are not lowered, and the burden on the environment is minimized.

Examples of Each Ecofactory Cycle by Product

In item (4) on specific review proceedings, the construction materials, assembly method, and special function of products assumed when the ecofactory concept is implemented for each product will be clarified. Here, we present a case study of ecofactory technology targeting vending machines. This example is referred to until the end of this discussion.

(1) Conception of vending machines manufactured by an ecofactory technology system

Appearance:

Appearance: Unchanged from the conventional product

Function: Unchanged from the conventional product (design information loaded into memory)

Strength: Unchanged from the conventional product

Weight: Lower than conventional product

(2) Parts and operation-specific technology

- Appearance

Plastic exterior panels: These will be constructed from one type of plastic. Therefore, a plastic with excellent recyclability will be developed.

Metal exterior panels: These will be coated by paints that easily peel off and evaporate in special environments. The panels will be made from uniform materials and include reinforced materials. New paints and coating technologies will be developed.

Glass panels: These will be easily removed during disassembly. Therefore, installation technology that performs well, even when packing is not used, will be developed.

- Internal construction materials

They are sturdy while in use, but can be easily taken apart during disassembly. Therefore, design methods will be developed giving priority to dismantling properties like anisotropic assembly and joining techniques (easy disassembly by applying pressure from different directions during disassembly than during use) and unidirectional assembly.

- Money handling system

On a printed circuit board consisting of a data processing unit, sensor unit, and drive unit, each unit performs a separate process. The drive unit is constructed from various types of uniform materials that are returned to the recycling process unchanged. Based on the system configuration of the disassembly process, by writing disassembly support data into the memory in the data processing unit, a more efficient disassembly process can be designed.

- Drive unit

Standard transformers and motors are used. The unit is constructed so that it can be disassembled in one process.

- Refrigeration system

The types of compressor and pipes are formed into a unit to enable disassembly in one process. They are constructed from copper, steel, and one type of plastic.

(3) Element technologies required in each process

- Design process

Overall, in order for disassembly to proceed smoothly, the design allows for disassembly from one direction. Design is improved so that the use of screws is avoided as much as possible and disassembly by only pulling becomes possible. When screws must be used, the screws' positions and shapes allow easy discrimination. In addition, new fastening methods will be developed (design for easy disassembly). The dismantling methods in the disassembly process are stored in memory or on hardcoded markings on the surface. While giving priority to disassembly characteristics, in order to simultaneously achieve manufacturability, resource and energy conservation, concurrent design technologies will be developed.

To facilitate separating materials after disassembly, the units and types of material used will be designed to be as few as possible. In addition, by marking each part to

indicate its type of material, only the same materials are collected and recycling with a high degree of purity will be possible. When made from uniform construction materials, horizontal recycling of materials whose strengths are maintained becomes possible.

- Manufacturing process

Advances in assembly robots are continuing so that the degrees of freedom in designs giving priority to disassembly are not harmed by restrictions in the manufacturing process.

If the burden is not lightened on the recycling process, there is the fear that energy consumption in the recycling process will increase. Therefore, highly reliable processing technologies must be developed so that materials with intermediate purity allow recycling with low energy consumption in the recycling process and the materials can be used in the same way as highly pure materials.

- Disassembly process

Advanced disassembly robots will be developed to remove each unit from the main body and dismantle each one into separate materials.

- Recycling process

A variety of recycling technologies will be developed to recycle materials back into raw materials.

Since at times mixed materials that cannot easily be separated into uniform materials and materials corrupted during use are the targets, horizontal recycling and multi recycling must be realized. In this case, after shredding, the materials are selected by specific gravity and recycled by rheorefine technology.

Conclusion

As explained before, ecofactory technology involves research that fuses the mechanisms of independently functioning conventional manufacturing systems and reduction systems to create and reduce products with good overall efficiency. In order to implement this idea particularly in machine fields, the idea of reusability that does not completely encompass the concepts and evaluation standards of existing machine technologies is included in the machine technology field. Previous ideas and paradigms in machine technology will be entirely revamped. The research elements will be pioneering, difficult, and rich in innovations.

However, if this technology does not become technology that will be used in society, it will be a failure. Consequently, sufficiently examining the relationship with social systems is required. Social systems must be reformed in response to necessity.

Japan has made efforts to build a world class manufacturing system. However, current waste processing problems are becoming larger and radical solutions are being sought. When improving manufacturability occurs at the individual corporation level and individual collection processing is performed by corporations, it becomes difficult to solve these problems.

Specifically, if manufacturability and resource conservation are not considered for the whole social system, these issues will be difficult to solve. In fact, waste processing problems include home appliances and automobiles and these problems will continue to be studied in various fields. Studies in one corporation and one industry will run into huge barriers in areas related to social systems. These barriers are not being discussed.

Discussions on ecofactory technologies and their conceptions are gradually gaining more depth in this advanced research. Introducing and establishing these kinds of ideas into social systems will be extremely difficult under the current circumstances. However, this is not a problem that can be neglected. It is crucial for R&D on ecofactory technology to be rooted in society.

While these discussions are underway in the planning committee, I would like to gain your support so that we can produce results in this pioneering research.

Chiba University Professor on New Machine Tool Technology

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[Article by Professor Yoshimi Yoshida, Mechanical Engineering Course, Faculty of Engineering, Chiba University]

[Text]

Introduction

Last September, I had a chance to attend the 10th European International Machine Tools Trade Show (10. EMO) held every four years in Hanover. Although this is my second consecutive trip to this trade show in Hanover, I looked forward to this trade show because it followed events that will change society like the unification of East and West Germany and the unification of the European Community (EC). This was a truly interesting trade show where my expectations entailed what metamorphosis would take place in the machine tool industry in the EC with Germany having a new social situation for the first time, or what measures should be taken to escape the current recession.

I will develop this discussion by comparing the current state of machine tool technology overseas within this climate to the actual state of machine tools in Japan.

Overall Impression of 10. EMO

Although this trip to 10. EMO lasted only a few days, September 14-16, it became, unfortunately, a somewhat unfocused trip. Exhibition halls of various shapes were adeptly located on the very large site of the trade show so that even people who attended only once could point

them out. Of these, there were various exhibits, including one of machine tools in the broad sense not simply the machine tools themselves and exhibits of peripheral equipment (in fact, a wide variety of machine exhibits), and software exhibits. I think the show needed to be longer in order to see the whole show.

As a result, while taking into account this schedule, I would like to first convey my impressions of several exhibits related to machine tools in the narrow sense.

The number of attendees was relatively few on the first day and I was able to survey the exhibits with no trouble. However, on the second and third days, the expansive site was crowded by the influx of visitors who were there to conduct business. But compared to the congestion at the machine tools trade show in Japan, I was able to comfortably survey the site.

This time, 1,887 companies from 37 countries had exhibits. Although I covered about half of the whole site, it seems a portion of the companies declined to display products, so the booths were changed into lounges or event displays. Consequently, the number of exhibiting companies was decreased slightly. However, this may also reflect the poor business climate.

Moreover, large-scale factory automation (FA) system exhibits of flexible manufacturing systems (FMS) or computer-integrated manufacturing (CIM) which occupied a very large portion of the exhibits and would have a substantial impact were almost totally absent. I had the impression that they were replaced by a vast number of exhibits on flexible manufacturing cells (FMC, i.e., machining centers and turning centers) as system configured machine tools. Nevertheless, their actual operation demonstrated a degree of technical completion. A similar trend occurs in Japan's trade shows, so trade shows have become very practical. Exhibits of large-scale systems used either posters or videos and aimed at exhibiting the technology.

There were few new products, but there were products that returned to the technology source with the result of appearing to be relatively new products. Companies exhibited the history of technology. A shaver manufacturer exhibited old products along with new products and illustrated the history of the technology. This seemed to indicate the company's position of firmly protecting its brand. Today, lathes with slant beds have the basic form of numerically controlled lathes. Lathes with a shallow incline of the slant bed and a slant bed structure with an incline closer to a horizontal bed were exhibited. These products exhibited the technical issues of being able to stably process given the manufacturing technology. I saw many products that demonstrated autonomy, but this trend was already apparent at the previous Hanover Messe. Of course, the trend of developing numerical controls is unchanged. (About 25 percent of these exhibits were Siemens' systems.) However, similar to what is seen in Japan's machine tool industry, almost all of the companies have not specialized to a particular type of equipment. This is not a departmentalized system and each company has taken the position that its type of equipment is important.

This machine tools trade show was extremely interesting as the first large-scale trade show after EC unification. German corporations, as explained earlier, designed a technological tradition based on each corporation placing importance on its own types of equipment. I felt that even in other countries, beginning with France and Italy, the corporations in these countries are trying their best. Efforts are being made to prevent falling behind Germany.

Forgive the short time I spent and the small amount of material I collected, but I did briefly touch on the technical aspects and observed the following characteristics. Machine tools for metal die processing (in particular, machining centers and turning centers) were prevalent. Therefore, many machine tools were equipped with multiple axes control functions and the elements to control them (spindle heads or manufactured product installation devices) varied. I saw the technical developments to achieve this. More complex machining centers equipped with grinding heads were present as were equipment with more complex laser heads. I also saw machining centers having multihead spindle heads to improve productivity. In addition, this interesting trade show presented measures to improve the hardness of machine tools, as well as developments underway on turning centers (called machining centers) with a space-saving downward spindle assembly and excellent chip removal.

Comparison with new technology trends in Japan

The issue facing corporations that manufacture machine tools domestically and abroad is to manufacture machine tools for users that will maintain higher quality (higher precision) manufactured goods created more rapidly (speed up) and more inexpensively (more efficiently), and are safely and easily operated by people. Another task is to provide machine tools that consider unmanned operation to save time and improve the workplace environment.

To respond to the demands of this era, one needed technology for future machine tools is technology to maintain precision in machine tools over a long life span. That is, the manufacturing technology will improve the reliability of work precision. In addition, the structural materials for machine tools were evaluated as inferior to those in Europe and the United State, resulting in rapid deterioration in precision. However, it is believed the structural techniques for machine tools can solve this problem today.

Another technology is to develop advanced automation or systematization of machine tools. There will be composite technology development able to comprehensively process a variety of machine processes. Of course, developing machine tools that are economical will be necessary in the future.

3. Steps to improved precision

High precision machine tools are ultraprecise machining and grinding machine tools exemplified in mirror surface finishing. In spite of there being machine tools that guarantee operating precision in units of nanometers (nm = 10^{-6}mm), recently, automation has been moving forward and the automation of ultraprecise machining has proceeded in the automatic processing of the mirror surfaces in magnetic disks and the polygon mirrors used in laser printers. Of course, we cannot forget the accumulation of basic technologies over many years used in this technological development. In this field, there is a great deal of excellent processing equipment in domestic products.

However, we cannot forget that the majority of machine tools used to manufacture this processing equipment depends on foreign machine tools. For example, there are the lathes of Schaoblin, cylindrical grinders of Schaut and Studer, and the precision surface grinders of Jung. These products are the results of efforts to improve within each of these companies. Unfortunately, Deblieg, the famous machine tool manufacturer on whose designs Japanese corporations have based their designs, did not have an exhibit. The saving grace was probably the remarkable machines announced by Dixi.

Recently, since artificial granite called granitan, which has superior oscillation characteristics, can be used in the other structural elements of the machine bed, there were corporations selling spindles in addition to selling granitan beds. ELB may be one company that successfully applied artificial granite to grinding beds. For these materials which exhibit thermal problems, ACO announced technical data and the development of epoxy compounds that do not have thermal problems (low thermal conductivity). The strategy is to possibly use them in the future.

2. Developing composites

One direction for future processing technology is composite processing. While high-speed processing methods and high precision machining methods have been used independently, in the future, a machining format (composite processes) that shares the characteristics from each methodology will be considered. A particularly striking example of this effect is A1 alloy processing. The high-speed A1 alloy process is used in machining fuselage parts of airplanes and various fans, thus, it has had a major impact. The heat generated during machining, due to high-speed machining, is decreased and thermal expansion of the parts is suppressed. In addition, by reducing the loss of tools, the parts are endowed with higher precision and efficiency. This utilizes the effect of reduced heat generation during processing which is one effect of high-speed machining.

Furthermore, there are new developments where lasers (YAG lasers) are introduced as machining tools into composite processes. 50W laser heads installed on one end of the turret spindles located in two positions are used as new composite process tools in cutting, quenching, and welding. This turning center is a model announced by Traubu. It is publicized for use in a variety of applications because it has almost no machining force and small thermal effects.

One development trend for machine tools is simple structures (simplification) where only improved characteristics of the structure can be designed. The other trend is developing more composite tools capable of machining functions. A machining center is representative of this type of machine tool. A number of tools housed in equipment by an automatic tool changer (ATC) can be automatically selected and changed in response to machining demands to perform a specific process. In general, however, angled parts are limited to parts processed by contouring, boring, and surface finishing by milling tools and boring tools. Further, 5-axes machine tools with an increased number of control axes are appearing even in Japanese corporations and complex shape processing is becoming possible. Thus, the use of machining centers is advancing. Although initially horizontal spindle machining centers were prevalent, vertical spindle machining centers for metal machining are gradually expanding and are now surpassing horizontal machining centers. Since there are limits to what a vertical axis machining center can machine, there are also machining centers for 5-sided machining equipped with an interchangeable spindle unit called an angle attachment or with a swiveling spindle.

Additionally, Scheiss developed a production center based on a machining center equipped with a machining spindle in the ATC. Concurrent with advances in composite machines are improvements in productivity.

3. Changing the structure

I also saw machining centers with new structures. A column that supports the spindle bed is the basic structure at Jung, a manufacturer of precision surface grinders, and is called the sunken column method. This has proven to be very effective for rigidity. Other sunken column machining centers using this structure have appeared. A model under development at O.M.V in Italy will be a stable, aesthetic machine center with an extremely low machine body and excellent rigidity.

In contrast, there was a machining center designed with an innovative workpiece installation method (CMS-Nord Productique in France). For example, instead of the usual surface for a boring machine, there is a large, square hole where a workpiece installation tool can be installed at the center. The workpiece is installed on each of the four sides and multi-spindle machining is possible. This method produces a suitable high rigidity workpiece spindle.

In contrast to machining centers, Japanese corporations also developed turning centers equipped with milling

functions like flattening and grooving on the side surfaces of round products in numerically controlled (NC) lathe functions. NC lathes are becoming more multifunctional and their use in composite machining tools is spreading. The same trend was evident at 10. EMO. Composite machines are being developed to the extent that an NC lathe cannot be distinguished from a turning center. This guarantees the position of system compatible machine tools that compose FMS (flexible manufacturing systems) as FMC and equips NC lathes with ATC and AWC (automatic work changer). Of these, turning centers (also called machining centers) having a vertical reverse spindle structure were announced. These models are based on almost the same idea as the models announced as space-saving NC lathes by Japanese corporations at the previous Tokyo International Machine Tools Trade Show. However, this time, machining centers capable of machining relatively large objects and supplemented with automatic tool changing and workpiece changing functions were announced. Emag's machine tool is representative of this type of machining center. Hessap and Weisser also made similar announcements.

Recently, grinders have come to be called grinding centers and NC grinders with composite functions are appearing. In this way, composite machining by multiple functions related to machine tool functions is progressing.

4. Improving productivity

Faster speeds, better precision, and more composites are the technical trends of machine tools in Japan to improve productivity. A similar trend is taking place in machine tools overseas. Increasing the speed of the spindle is based on the strategy of a sufficiently fast spindle (perhaps, for the sales policy), but not requiring an especially fast spindle in practical use. I thought speeding up ATC was a major publicity point at this trade show. Of course, similar speed ups in table transfers were announced. As for higher precision, the precision of finished products was announced and higher precision was demonstrated at this trade show. Results measuring all kinds of precision based on JIS 6201 were announced and the high precision of the machine tools was publicized. In this way, instead of examples showing actual measurements, I saw examples showing the rigidity of machines based on the meaning that the rigidity of the machine compensates for precision. Overall, there were machines where it was difficult to always say they had high rigidity designs, but in planar machining centers, I saw designs that maintained high rigidity appropriate for the column in spite of their relatively small sizes. Gantry-type machining centers were present, too. There was an ATC and machining center equipped with a modular multihead spindle (in this case, a 3-head spindle structure) from Fritz Werner. Moreover, there was a great deal of interest in the structure with a system to freely control the height of the front end of the spindle.

Similarly, there was a machining center from Chiron constructed from a twin head spindle to increase productivity. This model also eliminated the deficiencies of a single axis in a machining center.

Conclusion

I had a very short time to survey the show. The scope I surveyed was extremely narrow. In addition, for gear machine tools, for example, almost all of the famous machine tool manufacturers for gear machining exhibited machine tools. Moreover, I noted the importance of gears has not been lost. For example, in solving the noise problem of automobile transmissions, it is important to design for smaller sizes from the perspective of energy and resource conservation. Therefore, there is a demand for higher performance gear machine tools. Moreover, the tasks assigned to future machine tools for gear machining such as considering higher quality work material that should be machined are important.

These issues are not simply limited to machine tools for gear machining, but are problems shared by general-purpose machine tools. To solve the problems of high rigidity, high precision, and high performance, more innovative machine tool designs are being sought.

One solution to deal with these problems is the attempt to develop composites (regardless of the function and structure) in the broad sense. Although the opportunity exists for satisfactory speeds for fast machining, high-speed machining can also make high precision (composite) and managing high quality in machined products possible. When improving the reliability and lengthening the life span of future products are considered, high speed and high precision machining are necessary. This concludes my report.

MITI's Technical Aid Outlined

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[Article by Hidefumi Ikegami, manager, Project Group, Engineering Advancement Association of Japan (ENAA)]

[Text] The Ministry of International Trade and Industry (MITI) is conducting the following comprehensive surveys targeting developing countries:

(1) 1986—Overall coal utilization efficiency in China

(2) 1987—Determining the basic preliminary plan on energy resource use in China

(3) 1992—Survey of environmental conservation policies in developing nations (air pollution studies in China)

(4) 1993—Survey of environmental conservation policies in developing countries (air pollution studies in ASEAN countries)

(5) Planning survey of overall sacred tree charcoal utilization in China

In the 1986 survey (1) to study the overall coal utilization efficiency in China, industry and the people's welfare have been affected because of the supply shortage of coal, which is a principal energy source in China, caused by low utilization efficiency and poor transportation capability. As a result, the current situations in coal utilization, coal mines, and transportation were ascertained in terms of technology concerning the efficient use of coal, and related issues and problems were clarified. In addition, the applicability to China of efficient coal utilization technologies of Japan, Europe, and the United States was studied and various problems needed to draft policies on future industrial technology cooperation were proposed.

In the 1987 survey (2) to determine the basic preliminary plans for energy resource use in China, China which has a rich supply of energy resources has advantageous conditions to achieve stable economic development over the long term. However, since the foundation for the practical use of energy resources is incomplete, energy supply shortages limit economic development. Thus, the current circumstances and problems in the investigations, development, manufacturing and processing, transportation, and use of primary energy resources in China were determined. Additionally, a proposal was made on how the foundation for the practical use of energy resources should be prepared from the perspective of pursuing profit by both Japan and China.

In the 1992 survey (3) to study environmental conservation policies in developing nations (air pollution studies in China), based on the characteristics of the energy use in the target country of China, the industrial structure, the economic level, the environmental standards, and the possibility of local acceptance were examined. Suitable technologies that can be transferred from air pollution technology in Japan were explained.

Desulfurization technology for coal burning boilers in the industrial and public sectors and boilers in coal power generation plants moved towards techniques for technology transfer.

The following studies were performed in the target fields of the industrial and public sectors and the coal power generation plant sector.

(1) The target regions for the surveys in the industrial and public sectors were Nanking in Jiangsu Province, Wuhan in Hubei Province, Benxi in Liaoning Province, and Shenyang in Liaoning Province.

(2) The organizations that conducted the surveys of the coal burning generator sector were the Resource Division, Safe Environment Bureau (Beijing); Resource Division, Xi'an Thermal Plant (Xi'an, Shensi Province); Resource Division, Shinan Electric Power Design and Research Institute (Chengdu, Sichuan Province), and Sichuan Province Electric Power Industry, Baima Plant (Zigong, Sichuan Province)

The following surveys were mainly performed in the industrial and public sectors.

(1) Current technology conditions, overseas technology trends, and the domestic situation in Japan's smoke desulfurization technology and dust collection technology were examined.

- Completed developments or current developments exhaustively cover domestic and overseas development.
- The system flow, performance, construction costs, operating costs, and restrictions on construction and operation were established.

(2) Views on the factory production scale, pollution generation conditions, methods to train skilled workers, and local organization were surveyed in local surveys in China.

(3) These local surveys were analyzed and organized into the

- problems of pollution prevention measures and policies to address them, and
- air pollution prevention technologies that must be transferred.

The following major surveys were performed in the coal thermal power generation field.

(1) Concerning Japan's desulfurization equipment for thermal power plants

- The types of desulfurization equipment currently under development or in the development phase were exhaustively selected.
- The degree of completion, characteristics, construction costs, operating costs, and restrictions on the construction and operation were established.

(2) The capacity of China's thermal power generation plants, sites, fuel utilization characteristics, operating conditions, and pollution generation conditions were investigated.

(3) Situations previously confronted in desulfurization technologies in China and future directions were studied.

In the 1993 survey (4) to study environmental conservation policies in developing countries (air pollution studies in ASEAN countries), suitable technologies for ASEAN countries (Indonesia, Philippines, Thailand, Malaysia) were selected from Japan's air pollution prevention technologies of dust collection and smoke desulfurization. Based on surveys of combustion technology, fuel policies, and environmental standards of the ASEAN countries, the expectation is the objective of

promoting the transfer of technologies most suited to the target country will be carried out.

These surveys are based on the following surveys in Japan and overseas surveys and will give direction to the environmental technologies suited to ASEAN countries.

(1) The current state of technology, overseas technology trends, and the results of surveys on the current domestic conditions of Japan's smoke desulfurization technology and dust collection technology will be examined in the following way.

- Completed development or current development will exhaustively cover domestic and overseas development.
- The system flow, performance, construction costs, operating costs, and restrictions on construction and operation will be established and appropriate technologies for ASEAN countries will be selected.

(2) Through surveys conducted overseas for each target country and each region, views will be surveyed on the manufacturing scale of factories, manufacturing process, current state of pollution generation, methods to train people, required investments in pollution prevention facilities, surveys of needs, regulatory state of environmental laws, and government organizations.

(3) These local survey results will be analyzed for

- problems and policies seen from the manufacturing process,
- problems and measures to prevent pollution, and
- air pollution prevention technologies that must be transferred.

Through the implementation of a commissioned study in the comprehensive development planning study in 1986, organizations connected to China and technology exchanges were promoted by the Engineering Advancement Association of Japan and the implementation of projects was encouraged. On 23 November 1992, the China National Planning Committee, China International Engineering Consultative Company (CIECC), and the Japan International Cooperation Agency signed the Comprehensive Utilization Planning Study on China's Sacred Tree Coal. A full-scale study began on realizing the COMPLEX project on sacred tree charcoal use.

COMPLEX is slated for establishment in Baotou, which is the largest industrial city in Inner Mongolia. The raw material is coal, and municipal gas, urea fertilizer, methanol fuel, and acetic acid are produced. The complete consumption of the products by domestic demand is expected.

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